CHEMICAL CONVERSION OF WOOD RESIDUES—P. 248

Forest Products Journal

Vol. VIII, No. 9 September, 1958

Logging by Helicopter? Read the 14 pages of expert opinion from FPRS Helicopter Logging Session. Start p. 9-A

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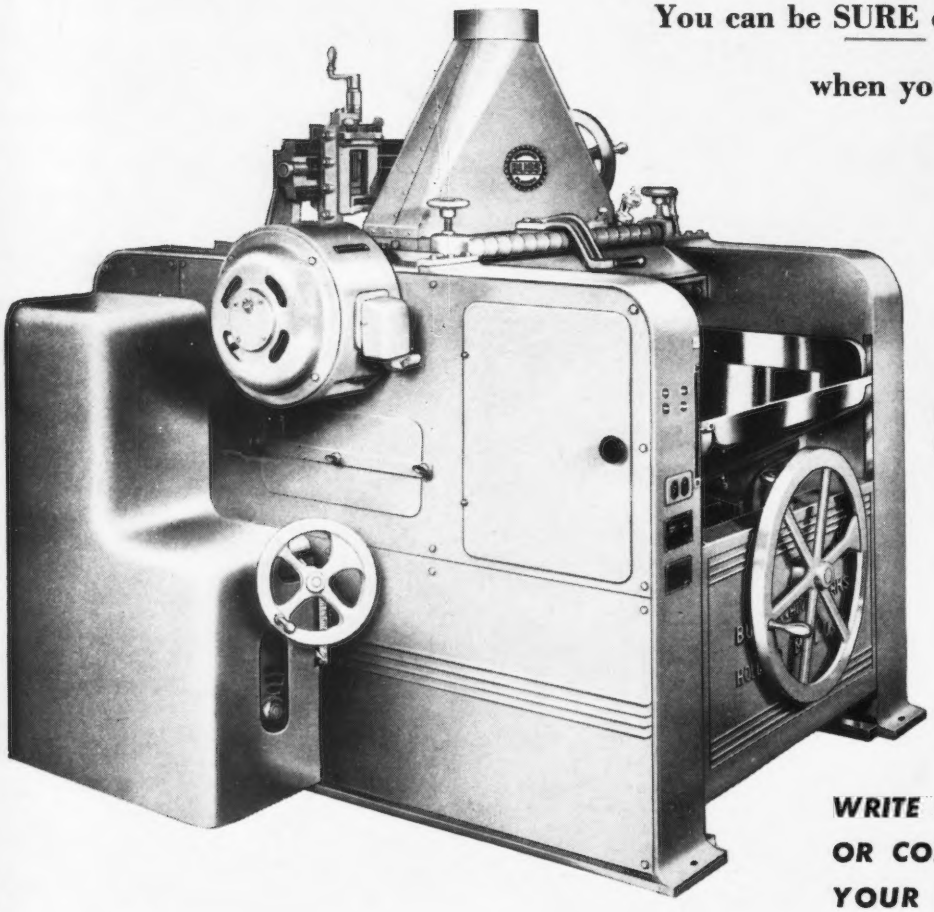

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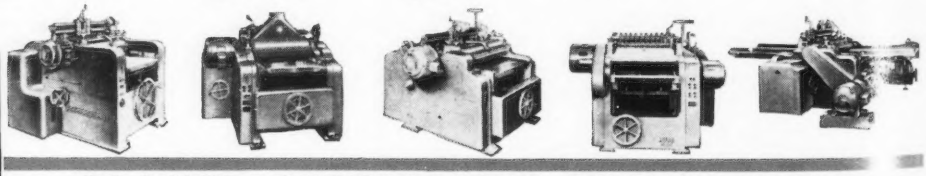

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IMPORTANT FPRS DATES

Oct. 2–3, 1958: Upper Mississippi Valley Section Meeting, Eau Claire, Wis.

Oct. 12, 1958: Mid-South Section Meeting, Baton Rouge, La.

Oct. 24, 1958: Great Lakes Section Meeting, Grand Rapids, Mich.

Oct. 27–28, 1958: Pacific Northwest Section Meeting, Vancouver, B. C.

Oct. 28, 1958: Northeast Section Clinic Meeting, Jamestown, N. Y.

Oct. 30–31, 1958: Northeast Section Meeting, Lancaster, Pa.

Nov. 6–7, 1958: Carolinas–Chesapeake Annual Section Meeting, Charlotte, N. C.

June 28–July 3, 1959: Thirteenth National Meeting, San Francisco, Calif.

On The Cover

The possibility of using helicopters to fly logs out of the forest has been argued pro and con for some time.

Three months ago, at the 12th National Meeting of the Forest Products Research Society, loggers and representatives of the maturing helicopter industry got together in their first formal technical session to find out exactly what the helicopter can do right now, what will be needed before we can log by air, and what the probabilities are for future full-scale log movement by helicopter.

In this issue are presented the five papers, and the discussion that followed, at this historic session at the FPRS 12th National Meeting.

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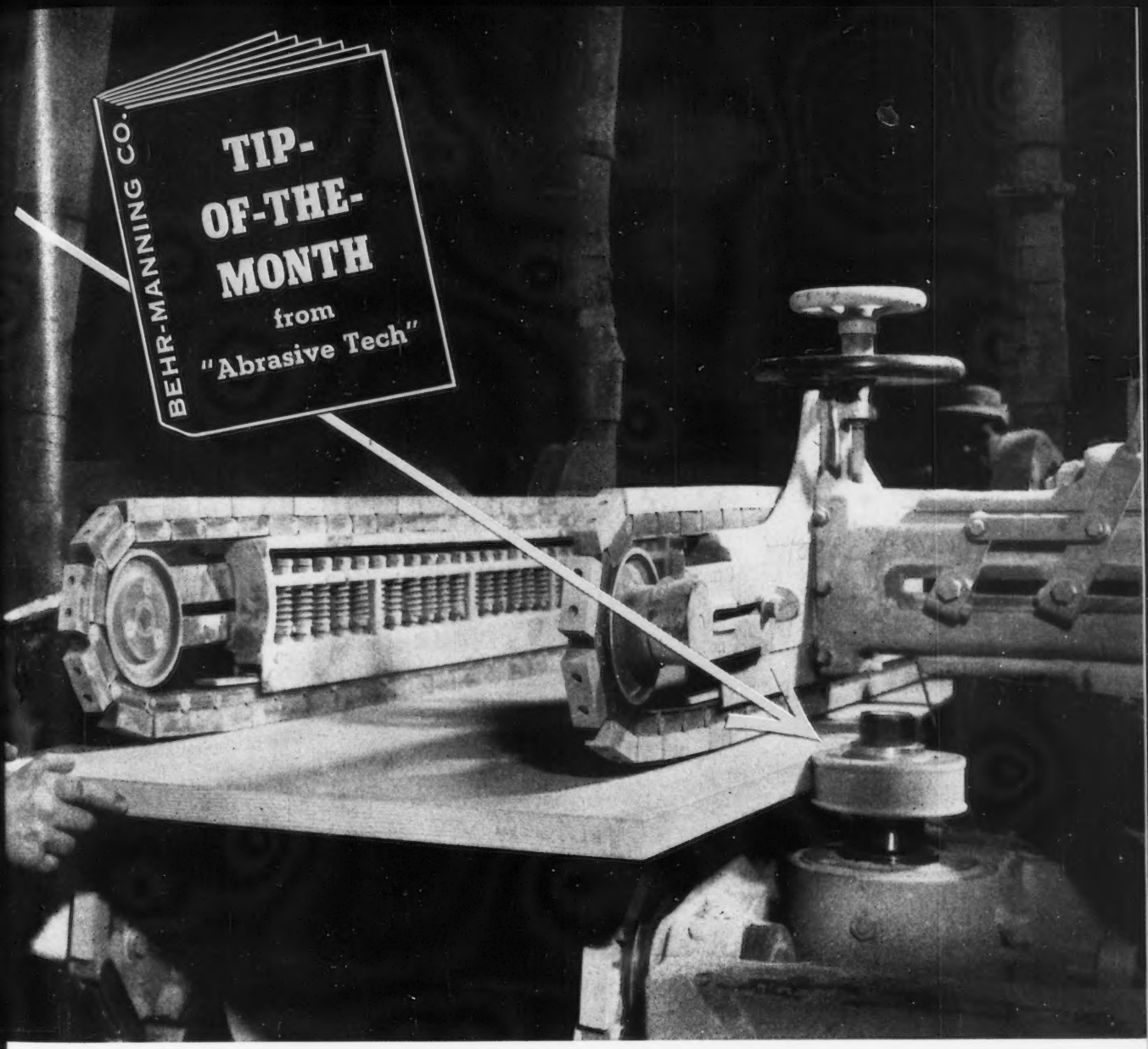

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FPRS NEWS-DIGEST

Volume VIII SEPTEMBER, 1958 Number 9

Joint FPRS-NLMA Careers Booklet Underway

A draft of "Opportunities Unlimited", the joint NLMA-FPRS career opportunities booklet designed to attract high school students to the forest products industries, was reviewed by members of the NLMA Special Committee on Education at a May meeting in Santa Barbara, Calif. The Committee recommended the booklet be published subject to such minor revisions as may be necessary.

The permanent staff officer of the Committee, Gerald F. Prange, was instructed to maintain liaison with the Forest Products Research Society in the development of the booklet. Indications are that the booklet may be published this fall, possibly in conjunction with the NLMA November meeting.

FPRS Sections to Cooperate in Distribution

Distribution of the booklet will be undertaken in varying ways in different locations, and will draw upon the interest of local organizations and individuals. Names and addresses of all FPRS national and section officers have been forwarded to NLMA by the Executive Office, so these persons can be called upon to assist when the pamphlet is ready for distribution.

FPRS's Wangaard Did Early Work on Booklet

The Industry-Education Division of FPRS has long been interested in publication and distribution of literature about the forest products industries for high school students. They recognized the need of a coordinated industry effort. In preparation for the FPRS 1955 National Meeting in Seattle, the Division under the chairmanship of Fred Wangaard, Yale University, prepared a format for a proposed pamphlet.

L. J. Carr, retiring FPRS President, was designated to present the booklet to NLMA and propose that the lumber association underwrite cost and distribution, utilizing both the contacts of NLMA and those of FPRS. At their Nov. 1955 meeting, the NLMA Board of Directors recognized that this proposal by FPRS had great merit for the industry.

A year later, the governing body of NLMA approved the cooperation of NLMA with FPRS to develop a program directed toward interesting capable young high school students in seeking careers in the forest industries.

In Nov. of 1957, the directorship of NLMA established a special Committee on Education to work on an education program, authorizing the services of a full-time member of the Technical Dept. Staff for the purpose of coordinating and implementing the education program on the part of the industry.

The program outlined was publication of a career opportunities booklet prepared in cooperation with FPRS for distribution to high schools and universities throughout the country, preparation of a more detailed booklet for education guidance people, and providing a substantial amount of funds in the 1958 budget for preparation of these publications.

Other organizations throughout the industry have also maintained interest

Samples of wood residue are studied by, left to right, Walter Cates, vice president of the Georgia Chamber of Commerce, Scott Candler, director of the Georgia Dept. of Commerce, Rufus Page, state and federal forest products technologist, and Frank Albert, director of the Georgia Forest Research Council. Page is directing the study, and Cates and Candler will pass on the data to industries interested in locating in Georgia.

Georgia Starts Residue Survey

A $36,000 state-wide wood residue survey in Georgia got underway recently on a county-by-county basis, directors of the Georgia Forest Research Council and Dept. of Commerce report.

The survey was launched to provide up-to-date data on the availability of wood by-product raw material in the state, and to help industry pick profitable spots to establish wood-by-product using plants in Georgia. The study is pinpointing the locations of all types of wood residue.

The study will be carried out in three stages: the development of wood waste conversion factors, listing the locations and types of residue, and compiling the information into a report and posting it on IBM cards.

in ways of attracting good students. In the past, the Society of American Foresters in cooperation with the Northern California Section of FPRS, and Calif. State Dept. of Natural Resources prepared a booklet. The Committee on Education of FPRS Northeast Section also prepared a booklet.

Members of the NLMA Committee on Education are R. H. Berry, Scott Lumber Co., Chairman; L. J. Carr, L. J. Carr & Co.; N. B. Giustina, Giustina Bros. Lumber Co.; H. B. McKean, Potlatch Forests; T. L. L. Temple, III, Southern Pine Lumber Co.; William Van Beckum, The Pacific Lumber Co.; and G. F. Prange, Secretary for the Committee and special staff member appointed by NLMA.

Opening of New Vancouver Lab to Be Attended by Pacific NW Sec. During Oct. Meeting

An Oct. meeting, the 27th and 28th of the month, will be held by the Pacific Northwest Section in Vancouver, British Columbia, Section officers report.

Registrants will attend the opening of the new Vancouver Laboratory of the Forest Products Laboratories of Canada. A symposium on Bond Quality Evaluation will be held at the Canadian Laboratory.

Two technical sessions are planned, one dealing with "Western Red Cedar Utilization" and the second will discuss fiber, structural plywood and gluing research. A field trip and a dinner will complete the program.

Two October Meetings to Be Held by Northeast Section

Two Oct. meetings are planned by the Northeast Section, J. Allan Hauter, program chairman, announced recently. On Oct. 30 and 31, the annual meeting of the Section will be held at the Hotel Brunswick, Lancaster, Pa.

Preceding the annual meeting, a one-day clinic on "Trends in Furniture Design, Materials and Methods" will be held Oct. 28, at Jamestown, N. Y. for members of the Jamestown Area Furniture Mfgs. Assoc.

Mid-South Section to Meet Oct. 13, at Baton Rouge

Louisiana State University at Baton Rouge, will play host to the Mid-South Section for its Fall meeting on Oct. 13, Section Officers announced.

FPRS President Eason and Executive Secretary Rovsek will speak at the Luncheon during the meeting on national activities of the Society. A featured paper, "Wood in the Public Temple of the Southern Pine Lumber Schools", will be presented by Latane Co., Diboll, Texas.

Sawmill Automation Theme of Upper Miss. Valley Meeting Oct. 2–3, at Eau Claire

Mechanization of sawmilling will be the subject at the Upper Mississippi Valley Meeting, Oct. 2–3, at Eau Claire, Wis., Paul Lane, Section vice-chairman reports. The meeting will begin the evening of October 2 with a social hour, buffet supper, and speaker. Several papers and a panel discussion will be held the following day. Plant tours are scheduled for the afternoon of October 3.

"The Decision to Automatize the Sawmill" will be the topic of a paper by Milton H. Mater, Mater Engineering, Corvallis, Ore. B. Detjen, McDonough Mfg. Co., Eau Claire, Wis. will speak on "The Role of the Resaw in Sawmill Automation". W. C. Finley, Battelle Memorial Institute, will speak on "Future Developments in the Forest and Wood-Using Industries".

The panel discussion on "Practical Evaluation of Automation" will include: W. Arthur Parker, Red Lake Indian Mills, Red Lake, Minn.; D. N. McRae, Connor Lumber & Land Co., Laona, Wis.; E. Erickson, Erickson Hardwoods, Inc., Onalaska, Wis.; Carl Dahlberg, Dahlberg Mill, Keewatin, Minn.; and G. H. Houghton, Jr., Calumet & Hecla, Goodman, Wis. F. P. Loveland, Jr., Loveland & Assoc., Chippewa Falls, Wis., will moderate.

Moisture Relations to be Discussed at Great Lakes Section October Meeting

Moisture relations will be the theme of the Great Lakes Section Meeting, planned for Oct. 24, at Grand Rapids, Mich., N. C. Franz, Section Secretary reports.

Papers to be presented at the meeting are: "Atmospheric Moisture and Wood" "Plant Relative Humidity Can be Controlled", "Profiting From Moisture Control", "What Makes Plywood and Other Wood Products Warp?", "The Importance of Moisture in Finishing Systems", and "Moisture Problems in Furniture Construction".

Forest Fires to Be Studied at New Georgia Laboratory

Plans to build a forest fire research laboratory near Macon, Georgia, have been announced by Joseph F. Pechanec, director of the Southeastern Forest Expt. Station, Asheville, N. C.

A joint undertaking of the U. S. Forest Service and the State of Georgia, the new laboratory is expected to play a big role in helping the South protect its valuable woodlands from fire. The laboratory is scheduled to begin operating in 1959.

THE PULP AND PAPER Division of the U. S. Forest Products Laboratory has recently been awarded a Distinguished Service unit for research that helped to bring little-used hardwoods into use for pulp and paper. Laboratory Director J. A. Hall (left) and Division Chief Gardner H. Chidester look over the letter of notification. The award is the highest unit citation given by the U. S. Dept. of Agriculture, and the Division was the first Forest Service unit ever to receive this honor.

NOTICE

To: Potential 1959 National Meeting Authors

If you wish to submit a paper for the 1959 National Meeting at San Francisco, your suggested title and brief description of the paper should be directed either to the Technical Program Chairman, Dr. E. S. Harrar, School of Forestry, Duke University, Durham, N. C.; the individual Division Chairman; or the FPRS Executive Office.

At the 1959 Meeting, Technical Sessions will be held on the following subjects:

Glues and Gluing	Packaging
Wood Finishing	Quality Control
Chemical Utilization	Logging
Wood Machining	Industry-Education
Lumber Manufacturing	Veneers & Plywood
Wood Drying	Merchandising
Wood Preservation	Wood Composition Board

Your description should state the intended scope of the paper and individual features of the work that will in your opinion justify its inclusion on the National Meeting Program.

Some of the Divisions are tentatively planning two sessions. The Wood Finishing Division plans two such meetings with one on new processes and materials. Again this coming year, the Chemical Utilization Division will hold one technical symposium and one general session. The Wood Preservation Division hopes to cover fire retardant treatments at their session.

BUSINESS NOTES

• Housing Starts

In July the seasonally adjusted annual rate of private starts climbed to 1,060,000, highest level since Jan. 1956. July activity pushed the annual rate of private starts for the first seven months of 1958 to 1,013,700, compared with a year-ago pace of 970,000. Actual housing starts in July, public and private combined, amounted to 1,041,000. This was 4,000 units below June but the decline, less than usual for this time of year, was due entirely to a drop in public units.

NLMA Lumber Letter, Aug. 15, 1958

Several Washington sources predict there will be between 1,200,000 and 1,300,000 new homes started this year. June starts were 104,500 or at an annual rate of 1,090,000, most since Aug. 1956, when it was 1,136,000, according to the Bureau of Labor Statistics.

Housing Trends, Aug. 1958

• Lumber Production

NLMA figures place lumber output for the first half of 1958 at 15,443,000,000 board feet—nine per cent below the same period last year. June output, estimated at 2,810,000,000 board feet, was three per cent below the same month of 1957.

For the five weeks ending Aug. 2, new orders were 23 per cent above production. Compared with a year-ago, the new order figure was up 14 per cent while production was down three per cent.

• Furniture

June shipments were 7 per cent below last year. June orders were 9 per cent off from last year. Cancellations during the first half were 10 per cent less than last year, and unfilled orders on June 30 were 20 per cent below the same date in 1957.

NAEM Monthly Statistical Report, June, 1958

Machinery Show to Be Held at Southern Pine Assoc. Meeting

A machinery exposition will be held in conjunction with the 44th annual convention of the Southern Pine Association in New Orleans next year, S. P. Deas, the Association's executive vice-president, announced recently. The show will be in the Municipal Auditorium, April 11, 12, and 13.

Deas reported that prospective exhibitors for the 1959 show had been given 10 months' advance notice to provide ample time for arrangements and that firms which have not exhibited previously had requested reservations.

President's Column

Eason Calls Research New Pioneer Symbol in FPRS Acceptance Speech

MADISON, WIS., June 24—This is the greatest honor that has come to me in my life, with the exception of my wife saying, "I will."

W. J. EASON

Working with the Forest Products Research Society has been a very rewarding experience since I first became actively associated with it several years ago.

This moment is the high point in a long succession of very rich personal and practical experiences in connection with the people associated with the Forest Products Research Society.

The mere filling of the job of presidency shall not be very difficult, due to the wonderful foundation, past performance, and preparation that has been done by those who have preceded me. The difficult task will be in trying to improve or further develop the precedents that have been set for me. It is very satisfying to be associated with research, for in all of us there is a little bit of the pioneer; but since research has eliminated the covered wagon as a symbol of pioneering, we who live in this age are looking to other things now as symbols of pioneering.

To complete the circle, research itself may be one of the symbols. The pride and satisfaction of breaking through a frontier in a laboratory or on a production line is just as exciting as breaking through a frontier of mountains or plains in a covered wagon.

Using research as a vehicle of pioneering, we do not eliminate our vehicle, but create more vehicles in which to ride.

I have just returned from a trip around the world and had the pleasure of seeing a number of operations in the forest products field that interested me greatly. However, there was one which stood out as a brilliant example of research and development, aimed at retaining in public acceptance the products of the forest against the competition of other materials. In the two plants of the Mallinsons, headed by Sir Stuart Mallinson, I saw many products that weren't made a few years ago, but which are being made now as modified wood, paper, or wood in conjunction with other materials in order to serve new purposes and to retain the markets for products of the forest.

We have many instances of this in our country also, and it is the duty of the Forest Products Research Society to further and encourage this thinking.

The honor of this position which I am assuming today should be enough for one person. But on Sunday of this week we had the further pleasure of assisting in the dedication of the new Forest Products Research Society building, containing many products the direct result of research. Thanks to the wonderful donations of our friends and the untiring efforts of our fund-raising committee, of which Ray Berry was chairman, we have been able to get this building ready for dedication at this meeting.

We who produce products to house and serve others have now provided the material to house ourselves. This is the beginning of a new era in the Forest Products Research Society—an era of maturity, nurtured by those who have gone before us, that we all look forward to as a challenge; a challenge we accept based on the knowledge that we have an infinitely versatile, replaceable raw material whose characteristics can be altered in countless ways for vastly enlarged areas of use.

Looking into this new era of the Forest Products Research Society, I accept this position with great humility and deep appreciation.

New England Kiln Drying Assoc. Plans Fall Meeting Oct. 24–25

The 1958 annual fall conference of the New England Kiln Drying Assoc. is planned for Oct. 24–25 at Durham, New Hampshire, J. Harry Rich, secretary-treasurer of the organization, announced recently. The conference will be primarily an educational one, although a dinner is planned for Friday evening, Oct. 24. On Friday morning and afternoon discussions will relate to the need to understand and apply high-level operating techniques to meet the demands of present-day lumber seasoning and exacting requirements.

Mr. R. C. Rietz, U. S. Forest Products Laboratory, and Dr. H. B. Gatslick, N. Y. College of Forestry, will be on the program. A field trip to the kilns of the Champlin Box Co., Rochester, N. H., will be held on Saturday morning, Oct. 25.

Forest Insect and Disease Control to Be Studied by National Group

A special committee to help plan and coordinate forest insect and disease control on the nation's 484 million acres of commercial timberland has been appointed by the Forest Industries Council, the organization reported recently.

The Council is the forest policy coordinating body representing the American Paper & Pulp Assn., the National Lumber Manufacturers Assn., and the American Pulpwood Assn. The committee will be headed by Howard D. Bennett, secretary-manager, Appalachian Hardwood Mfgs. Inc. Vice chairman is E. F. Heacox, Weyerhaeuser Timber Co.

The objectives of the new committee are: to represent the forest industries in bringing about better understanding, coordination, and cooperation among all agencies interested in forest insect and disease control; to survey the forest pest situation throughout the U. S.; to stimulate interest in and action on forest pest control; and to encourage the formation of state and regional forest pest control committees where there is need for such committees.

Better Use of Aspen for Packing Studied by U. of Minn. Foresters

A system for making better use of aspen lumber in packing crates is being tested by forestry researchers at the U. of Minnesota. Foresters W. B. Wallin and D. M. Markstrom are working on a method for selecting aspen "members" according to the exact strength required for a certain load.

Packing and crating accounts for about 90 per cent of the aspen lumber manufactured and for more than a fifth of all aspen used in the state. The new system would tell the crate builder how big each member must be.

At present, the aspen grading system is based on "green strength" of the lumber. If it proves itself after thorough field testing, the system may be applied to other species as well.

NEW PUBLICATIONS

Is Spiral Grain the Normal Growth Pattern? P. L. Northcott. Advances the thesis that spiral grain in trees is the normal condition of growth and not an abnormality. Reprint from *Forestry Chronicle*, Dec. 1957. Available from the Vancouver Laboratory, Forest Products Laboratories of Canada, B. C., Canada.

News–Digest continued on page 29-A.

Directory of Forestry Economics Personnel to Be Compiled by SAF

The Society of American Foresters is planning a directory of people in the United States and Canada who are working in the area of the economics of forestry.

The Society announced recently that those interested in being included are invited to contact Professor A. C. Worrell, 360 Prospect Street, New Haven 11, Connecticut, for a data sheet.

NAMES IN THE NEWS

John L. Butler has been appointed a technical service representative for the adhesive resin department in Decatur, Ga., Reichhold Chemicals, Inc., reported recently. Mr. Butler was formerly director of the Hardwood Plywood Institute, and for several years was acting managing-director of its predecessor organization, the Southern Plywood Mfrs. Assoc.

Currently retiring from the U. S. Forest Products Laboratory is **R. P. A. Johnson,** chief of the Division of Physics and Engineering, who has terminated over 50 years of Government service at reaching the compulsory retirement age of 70. Mr. Johnson has been a member of the Laboratory since 1918 and in charge of engineering research since 1947.

Paul Gilbert, New York advertising space salesman, has been appointed East Coast Advertising Representative for the Forest Products Journal, the FPRS Executive Office reported recently. Mr. Gilbert is expected to increase the Society's effectiveness in calling on East Coast advertisers.

Two new members have been appointed to the faculty of Yale University School of Forestry recently. **Zebulon W. White** has been named as Professor of Industrial Forestry, and **Jesse H. Buell** as Assistant Dean of the School. Mr. White, previously a manager of an Arkansas firm, succeeds E. T. F. Wohlenberg, now retired. Mr. Buell was previously associated with the Rocky Mountain Forest Experiment Station as chief of the Forest Management Research Division.

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–316—Graduate mechanical engineer with experience in electrical work desired for a modern all-electric sawmill in the South. Experience should include maintenance and construction work. Reply should include age, education, experience, etc. Salary commensurate with experience and ability. (Sept.)

E–317—Dry Kiln engineer needed for hardwood concentration yard in metropolitan New York area. Excellent opportunity for man able to run a complete kiln-drying business. (Sept.)

E–318—A technical specialist needed for Northwest association. Must be under 30 with practical experience in technical service and research. Duties will entail organizing and maintaining a high-quality technical service primarily through personal contact in the field, directed toward government agencies, builders, architects, and lumber distributors. Will assist the association manager and aid the research committee in executing their annual program. (Oct.)

Employment Wanted

No. 477—Administrative, supervisory or cost analysis position desired. Holds B.S.F. and M.S.F. degrees. Has seven years practical experience in sawmilling and plywood. Has extensive background in plywood. Northwest preferred. (Sept.)

No. 478—Technical or engineering position desired. Graduate of Penn. State with B.S. in Wood Utilization. Has eight years of experience in production work and wide knowledge of most woodworking machinery, including hot and cold press. Familiar with many commercial species of veneers and the manufacturing of plywood. Hobby is cabinet making and design of wood articles. (Sept.)

No. 479—Technical or production position desired. Holds a B.S. in Wood Technology and degree in forest engineering from German technical university. Has experience as plant superintendent. (Sept.)

No. 480—Position desired by graduate with M.F. in Wood Technology. Has experience in product development and quality control. (Sept.)

No. 481—Graduate with M.S. in Lumber Kiln Drying and B.S. in Wood Utilization-Marketing, desires position. Experienced in quality control, yard work and sales. (Sept.)

No. 485—Position desired in research and development or quality control. Holds degree in Wood Technology. Has six years experience in gluing of wood. (Sept.)

No. 487—Position desired where there is opportunity for advancement. Has 4 years experience in kiln drying and general forestry. Married. (Oct.)

No. 488—Industrial engineering position desired with large woodworking firm, preferably multi-plant organization, furniture, veneer, or plywood. Will consider short-term assignments on a consulting basis. Graduate of German university with a degree equal to a B.S. in furniture manufacturing and industrial engineering. Completed apprenticeship as cabinetmaker and passed journeyman and master examinations with honors. (Oct.)

No. 491—Position desired in product development, sales, and sales engineering in particle board industry. Holds B.S. in wood utilization. Experienced in production of furniture, cabinetmaking and particle board manufacture. (Oct.)

Present and Probable Future Developments of Helicopters[1]

I. I. SIKORSKY and H. R. KWIATKOWSKI
Sikorsky Aircraft, Division of United Aircraft Corp., Stratford, Conn.

Although the present-day helicopter, like anything else, has its limitations, it can become one of the most valuable tools of the logging industry. The limitations of the helicopter do not lie in its versatility, but rather in the weight it can carry. Carrying timber out of woodlands on a regular basis may not be economical at the present time, but this versatile tool can already serve the industry in numerous other ways, such as in moving men and materials into otherwise inaccessible areas rapidly.

THE FIRST SUCCESSFUL HELICOPTER in the Western Hemisphere was built in 1939. Since then, the helicopter has proven to be a practical and economical tool in a variety of industries, serving in every continent, including both polar regions. To the military services in most parts of the world, the helicopter has become indispensable.

There is no reason why the helicopter in a progressive industry such as the lumber industry could not become one of its most valuable tools, enabling them to expedite and improve their work beyond that which can be accomplished by any other means or facilities. The present-day helicopter, like anything else, has its limitations. However, these limitations do not lie in the versatility of the helicopter, but rather in the weight it can carry. Carrying timber out of woodlands on a regular basis may not now be economical. However, this versatile tool can and will serve the logging industries in numerous ways.

Advantages of the Helicopter

This proven tool, a newcomer to the field of flying, is not as spectacular as the supersonic jet airplane, which can fly a man at the velocity of a revolver bullet and even faster. However, the helicopter may well be considered fully as important because it is the most universal vehicle of travel and transportation that has ever been created or used by man. This is not an extravagant

Fig. 1.—Two hundred of these 60-foot, 3000-pound poles were transported and spotted in pre-dug holes across rough, mountain terrain in southern California.

[1] Presented at Session VII, Helicopters in Logging, FPRS Twelfth National Meeting, held June 22–27, 1958, in Madison, Wis.

The Authors: Igor Sikorsky is a graduate of Petrograd Naval College, Russia. He studied engineering in Paris and for 2 years attended the Polytechnical Institute, Kiev. He came to the U. S. at the outbreak of the Russian Revolution, and started his first aeronautical venture in 1923. In 1939 he launched the first successful helicopter in the Western Hemisphere.

Henryk Kwiatkowski is a veteran pilot with experience as a bomber pilot and ferry pilot. He was a production engineer with Pratt and Whitney in Canada for six years before coming to United Aircraft Export Corp. He joined the Sikorsky Sales Department in 1957.

statement—it is merely a statement of fact. In contrast with any other means of surface travel, beginning with the pack animal and continuing up to the best modern trains, trucks, or cars, the helicopter requires no trails or roads. It is not hindered by landslides, snowed-in roads, washed-out bridges, canyons, or the like. It is completely free to travel anywhere. It can fly straight up, down, forward, backward and sideways, and hover in mid-air. It can fly over or around any object or obstacle as no other vehicle can.

The helicopter, unlike the airplane, needs no long runways for take-off or landing. The airplane has need of these and even more. Even a good airport would be of no value if roads and highways leading to it were not free and clear for passage. No such limitations affect the helicopter. It is able to take off from and land on any area large enough to hold its frame and, furthermore, even though such areas might not be available, the helicopter could hover over any spot and, with the use of the hoist arrangement, pick up or deliver passengers or cargo.

This list of unique characteristics would be incomplete if we did not mention still another valuable one. It is well known that every other means of transportation is limited in its cargo-carrying ability not only by the weight, but, more important, by the size, length, or bulk of the cargo. While trucks or freight cars can carry very heavy loads, yet they would not be able to transport bulky or extremely long objects. This also holds true with respect to the airplane transport and steamships; both would be unable to render useful services unless cargoes could be brought to and from the airports or piers, which is usually done by trucks or by rail.

Therein lies their limitation.

With the helicopter, on the other hand, there is no such limitation. Any object within its lifting capacity, regardless of its size or bulk or length, could be carried underneath the machine and delivered anywhere. Giant helicopters carrying considerably heavier cargoes will become available whenever such requirements will be forthcoming.

The above characteristics, in themselves, indicate the vast sphere of usefulness that may be offered by the helicopter in connection with such a great field as the lumber industry, which deals particularly with vast, virgin spaces, prospecting, carrying of personnel and materials, and arranging for the transport of its valuable cargoes out of areas where no roads exist.

Achievements of the modern helicopters can best be recognized from a list of a few world records, which are considered to be the most reliable yardstick for the evaluation of aircraft performance.

Altitude Without Payload

December 28, 1957 Cessna H-41 30,335 ft.

Altitude With 1000 Kg. Load (2204.622 lbs.)

April 26, 1956 Mi (Hound) 19,842 ft.

Altitude With 2000 Kg. Load (4409.244 lbs.)

April 25, 1956 Mi-4 (Hound) 19,744 ft.

Altitude With 5000 Kg. Load (11,023.110 lbs.)

November 9, 1956 Sikorsky S-56 12,100 ft.

Greatest Load Carried to an Altitude of 2000 Meters (6561.660 ft.)

October 31, 1957 Mi-6 12,000 klgr. (26,448 lbs.)

Maximum Speed Without Payload

(over 3-km. course)

November 11, 1956 Sikorsky S-56 162.7 mph

Speed for 100 Kilometers (62.137 mi.) in A Closed Circuit Without Payload

July 12, 1956 Sikorsky S-58 141.9 mph

Speed for 500 Kilometers (310.685 mi.) in A Closed Circuit Without Payload

July 12, 1956 Sikorsky S-58 136 mph

Speed for 1000 Kilometers (621.369 mi.) in A Closed Circuit Without Payload

July 12, 1956 Sikorsky S-58 132.6 mph

Distance in a Straight Line Without Payload

September 17, 1952 Bell 47D-1 1217.137 mi.

Distance, Closed Circuit, Without Payload

August 19, 1956 Vertol H 21 1199 mi

Relatively speaking, the helicopter is still a young aircraft. Yet it has proven beyond a doubt to be practical and economical for airline and various industrial uses. Sikorsky helicopters have amassed 1,500,000 flying hours. Commercially, the helicopter is operated for mail, express, and passenger services, power line construction and patrol, forestry service, crop dusting, spraying, health control, offshore oil drilling operations, fishing, geodetic surveys, geological surveys, fire fighting, seismic work, coastal patrol, and air-sea rescue operations. Several airlines are using them regularly, and some individual machines, operated by the earliest of such airlines, Los Angeles Airways, have in excess of 10,000 hours flying time. Helicopters are rendering valuable services to many industrial concerns such as oil operators on the Gulf of Mexico, Caribbean Sea, and other areas. Construction contractors who require considerable loads to be carried into inaccessible places for the erection of power lines and telephone lines, and for numerous other missions of different natures, are also using helicopters.

The lumber industry is a vast and important one. It is believed that the helicopter could offer it a completely new line of important services that could be accomplished by no other means of travel or other vehicle.

Helicopter world records as well as the list covering the services that could be rendered by a helicopter, which list, by the way, is far from being complete, may furnish some idea of what a modern helicopter can do. Fig. 2, "Payload vs. Range" for an S-58 helicopter, may give some information as to the capacity of a particular typical helicopter. Experience indicates that this aircraft can be operated for approximately $136.00 per hour. This figure would include practically all items of the cost of operating a helicopter, which are as follows: fuel and oil, maintenance and service, replacement parts, depreciation, insurance, and pilot's salary. (For a detailed analysis of these costs see Appendix I). Using this figure and the payload figure that has been given in the table for different distances, it is possible to estimate the cost of transportation by this aircraft. This represents an existing helicopter and current figures. However, with many improvements that are being added, a substantial further reduction in cost as well as certain increases in speed and considerable increases in lifting capacity, can well be expected in the immediate future.

The Prototype

As a result of the spectacular accomplishments of the standard S-58, a special crane-helicopter is now being

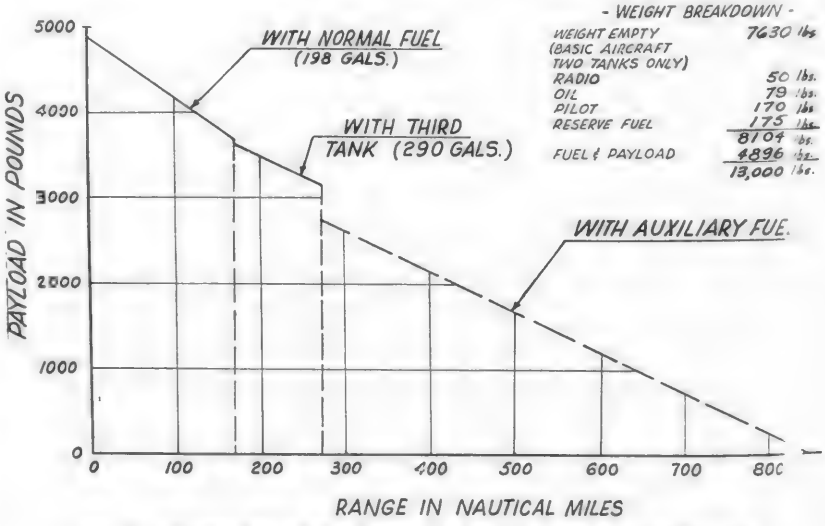


Fig. 2.—Payload versus range for an S-58 helicopter cruising at 85 knots with 20 minutes of reserve fuel.

designed. Based on proven transmission and rotor components that are now in use on the military versions of the S-56, the twin-engine prototype should be ready within the next three to four years.

The gross weight of this machine will be in the order of 31,000 pounds, and it will carry a payload of four tons. For shorter ranges, the aircraft could carry a payload of up to five tons. The machine, which is now being designed, is a true sky-hook. All the loads will be carried externally. The crew will include a pilot and a crane operator.

Assuming that the load being carried does not have an unusually large frontal area, the S-60 crane should be able to fly the four-ton load at 85 mph for a distance of 50 miles, deposit it accurately in place, and return to base at 100 mph. About 500 gallons of gasoline will be required to accomplish such a mission. On a usage basis of eight hours a day for 200 working days, and amortized over a period of five years, the operating cost of such a crane helicopter is now conservatively estimated at $310 per hour. This reduces to 93 cents per ton-mile.

As soon as jet engine power plants can be adapted to this design, the empty weight of the machine will be reduced and the payload will be increased by 50 per cent or more to six and one-half tons. As a result, the ton-mile costs will be reduced in proportion to about 70 cents to 80 cents per ton-mile.

Conclusion

The extremely interesting subject of the possible uses of the helicopter in logging operations can only be touched upon briefly in a paper of this size. However, there is no doubt that the helicopter, with its outstanding characteristics, could become one of the most useful and valuable instruments in the hands of a progressive lumber operator.

APPENDIX I

Approximate Direct Cost of Operation of the S-58

The following cost-of-operation estimate is prepared for a typical scheduled helicopter carrier with an annual utilization for each helicopter of 1600 hours. All prices used are taken to represent average conditions and it is realized that they will differ according to the type of service, environment, number of aircraft involved, and annual utilization. Table 1 shows differences in total direct costs with various annual aircraft utilization.

1. *Fuel and Oil:*

Fuel: 95 gallons per hour × $0.27 per gallon $25.65 per hour. (Actual fuel consumption under cruising condition is 88 gallons per hour, but for an operation involving short range flights, 15 to 20 miles, over-all average consumption will be approximately 95 gallons per hour.)

Oil and Aircraft Lubricants: Estimated conservatively at 5% of the fuel, or $1.28 per hour.

Fuel, oil and lubricant costs are therefore: $25.65 + $1.28 = $26.93 per hour

2. *Maintenance and Service:*

Airframe: Initial service experience already accumulated indicates airframe maintenance and service requirements of approximately 7 man-hours per flying hour. An average mechanic's and helper's salary is taken at $2.35 per hour.

7 hours × $2.35 per hour = $16.45 per flying hour.

Engine: Replacement parts such as spark plugs, etc., and the cost of major overhauls are estimated at $13.00 per hour.

Maintenance and Service thus totals: $16.45 + $13.00 = $29.45 per hour

3. *Replacement Parts:* The cost of minor parts likely to be required during line maintenance and during overhauling are estimated at $5.00 per hour. This would include such parts as gaskets, bushings, oil seals, and detail parts of the major components that might likely be replaced during subsequent overhauls such as gears and bearings.

Outside repairs and replacement parts costs to aircraft equipment such as instruments, electrical and radio are estimated at $7.00 per hour. (Replacement parts for the engine are already figured above with the overhaul cost, and the cost of replacement of major components, such as rotor blades, gear boxes, is figured under aircraft depreciation.)

4. *Depreciation:* Past experience indicates that the S-58 helicopter can be depreciated over 5 years, flying 1,600 hours per year, to a 20% residual value. Some of the previous models, the S-51, delivered in 1947, and now having over 8,000 hours flight time, are still in daily service.

Hence: $$\frac{\$253{,}000 \text{ less } 20\% \text{ residual value}}{5 \text{ years} \times 1{,}600 \text{ hours per year}} = \$25.30$$

Spare aircraft components utilized as replacement parts and for rotational maintenance. Such might include the following over the life of an aircraft.

	Estimated Costs
One main rotor head	$ 14,750
Two tail rotor heads with blades	6,900
Two sets main rotor blades	20,000
Two clutch assemblies (including fan)	7,970
One main transmission	13,900
One intermediate gear box	1,350
One tail rotor gear box	2,100
One set of hydraulic system components	10,845
Instruments and miscellaneous	20,000
One engine	40,000
TOTAL	$137,815

These are depreciated at the same rate as the aircraft.

$$\frac{\$137{,}815 \text{ less } 20\%}{5 \text{ years} \times 1{,}600 \text{ hours/year}} = \$13.80 \text{ per hour}$$

5. *Pilot Costs:* It is assumed for this estimate that each pilot flies approximately 800 hours per year, and his salary is estimated at $11,000 per year. This will also vary depending upon locality, type of service, and pilot's experience.

$$\frac{\$11{,}000}{800 \text{ hours/year}} = \$13.75 \text{ per hour}$$

6. *Insurance:* Based on the current rates available, an approximate rate of 8% per year is suggested for hull coverage. This may vary depending upon the operator, type of service, and number of aircraft in operation. In some cases S-55's have been included by airlines in fleet rates covering other aircraft.

$$\text{Hull Coverage } \frac{8\% \times \$253{,}000}{1{,}600 \text{ hours/year}} = \$12.65 \text{ per hour}$$

Passenger and public liability and property damage = $2.00 per hour.

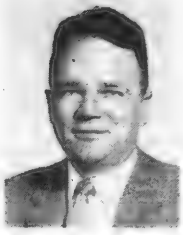
THE PRECEDING COSTS ARE TOTALED AS FOLLOWS:

Fuel and Oil	$ 26.93 per hour
Maintenance and Service	29.45
Replacement Parts	12.00
Depreciation: Aircraft	25.30
Spare Major Components	13.80
Pilot Costs	13.75
Insurance	14.65
Total estimated direct operational costs	$135.88 per hour

Table 1.—UTILIZATION

	Costs in Dollars/Flight Hour			
HELICOPTER FLIGHT HOURS/YEAR	800 hrs.	1,200 hrs.	1,600 hrs.	2,000 hrs.
Cost item				
Flight operations (pilot, fuel, and oil)	40.68	40.68	40.68	40.68
Maintenance, service, and replacement parts	41.45	41.45	41.45	41.45
Depreciation (5 years to 20%)				
Aircraft	50.70	33.75	25.30	20.24
Rotational spares	27.50	18.40	13.80	11.03
Insurance	27.30	18.85	14.65	12.12
TOTAL DIRECT OPERATING COST ($/Hour)	187.63	153.13	135.88	125.52
or DIRECT COSTS IN $/MILE	2.26	1.85	1.64	1.51
or DIRECT COSTS IN $/SEAT MILE				
12 Passenger "Continental"	0.188	0.154	0.137	0.126
16 Passenger Utility	0.141	0.116	0.102	0.094
or DIRECT COSTS IN $/TON MILE[1]	1.00	0.82	0.72	0.67

[1]Net payload that can be carried with fuel for 150 miles including 20 minutes reserve, plus an allowance of 300 lbs. above the basic weight empty for passenger seats, cabin interior furnishings and radio, is 3,846 pounds or 1.923 tons.



Helicopters for Forest Resource Managers[1]

CAL FERRIS

Director of Air Operations, U. S. Forest Service, San Francisco, Calif.

The advantages of mobility, perspective, and relative economy of helicopters (and also their limitations) are described very informally on the basis of extensive Forest Service research and carefully planned applications in California.

FORESIGHTED MEN FROM BOTH THE FORESTRY and aviation professions, please fasten your safety belts, especially those of you who are vested with responsibility for the efficient conduct of resource management programs. You will have to move fast if you hope to keep pace with your protection counterparts.

It is the purpose of this paper to point up some of the means that already are, or soon will be, available to assist you in accomplishing this worth-while task, with significant savings in men, machines, time, and money. Welcome aboard the *Palma Psychotica.* (This is not one of those foreign sport cars but merely the popular trade parlance for our favorite bird, the frustrated palm tree.) This short flight will cover some familiar ground en route to the objective and may bring interesting new horizons into view for many who have not yet enjoyed the thrill of exploiting the manifest advantages of mobility, perspective, and relative economy available only through the judicious use of rotor craft.

Preflight

Our forecast for this specific mission is moderate turbulence in the early stages, decreasing en route, with unlimited ceiling and visibility prevailing over the prime targets. Today's seasoned crew has been associated with helicopters since they were pioneered by our military services some 15 years ago. Their wealth of experience runs the gamut from near disastrous experimentation to triumphal conquests over complex problems comparable to those which traditionally face us all too frequently in wild lands management and protection.

The importance of other preflight activities such as planning the general conduct of the over-all mission and ample provision for alternatives and emergencies cannot be overlooked. Fortunately for those who are interested in developing helicopter services, we can suggest a standard check list format that will largely eliminate serious errors of omission and thereby alleviate many of the risks involved in setting up new helicopter services. In simple terms, no effort or expense should be spared to provide the best in safety, training, and support facilities. Generally speaking, research and development involving costly new helicopter equipment or techniques should be relegated to well-endowed sponsors such as manufacturers, government services, or cooperative industrial efforts. As these techniques become acceptable, top airmen must be trained and equipped to carry out such operations safely and efficiently. When these basic functions are supported by the appropriate development of facilities, the program is ready to go.

As an example of the foregoing, extensive Forest Service programs have largely relied on military helicopter units for evaluating the suitability of larger machines before they are available commercially. Our own helicopter is primarily used for developing and testing new accessory equipment, designs and techniques to determine acceptable standards of employment within the scope of their designed utilization. The new service is then released for limited field testing, during which the basic training of essential personnel is completed and additional supporting functions are established. These new services are then relegated to experienced commercial operators just as soon as they can meet our qualifications. When these civilian operators have demonstrated a new service that meets accepted performance standards, then and only then is it released to government foresters. Successful operations under this system now exceed 22,000 hours of rough, marginal helicopter flying into thousands of helispots without incurring any serious injuries, so this impressive record merits careful consideration by anyone contemplating comparable helicopter operations.

Take-Off

This panel on helicopters attests to the valid foresight displayed by our colleagues in forest green who were apparently quite busily engaged in conceiving all sorts of worth-while projects during the period immediately following World War II. Organization of a Forest Service helicopter unit corresponded closely to the founding date of FPRS. Let us sincerely hope that both endeavors continue to grow and prosper together.

Based on the very limited records compiled by the military services during the embryonic years prior to 1946, the Forest Service sponsored a gathering of top military and civilian helicopter technicians who outlined the program, format, and policy that are still in effect. In simplified form, this program provided for integration of expert aerial advisors who, in turn, insisted from the first that only the top qualified professional airmen would be screened and trained to carry out the unprecedented missions of servicing mountainous terminals reliably from the air. These men were, are, and always will be the prime motivators in operating aircraft safely and efficiently under comparable conditions.

For these crews to perform properly, a continuous series of test programs was established to determine the most suitable types of helicopters available for civilian use. This most favorable combination of men and equipment was the foundation of the early forest protection projects that resulted. In actual practice, it has always been the policy to devise and explore the pertinent capabilities of new equipment, usually acquired from the military services, prior to its availability through commercial charter operations. This general system, which worked so well in developing standard services such as transport of personnel and freight, reconnaissance and others, can be expanded into new fields of endeavor by the simple expedient of researching activities within the scope or capability of military or civilian investigations. Occasionally we find

[1] Presented at Session VII, Helicopters in Logging, FPRS Twelfth National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Cal Ferris has a BS degree in forestry from the University of California, with an aeronautical minor. He was the first forester-pilot with the U. S. Forest Service, and is a Lt. Col. in the Air Force Reserve. Ferris serves as a special aerial advisor to several governmental agencies.

Fig. 1.—Present helicopters can fly both men and materials to set up camps in remote areas at a fraction of the cost of otherwise necessary road building.

Fig. 2.—Bulkly items such as this small housing unit can also be readily moved from one location to another without the benefit of access roads.

that these adaptations can be carried out most expeditiously with integrated equipment, and so we own and operate one medium class helicopter, which is primarily used for these purposes.

When these basic functions are supported by the appropriate development of facilities, the big hurdles towards establishing helicopter services have been topped. We all certainly agree that, even with a skillful driver, the value of a fine car would be short-lived unless suitable roads were available; and yet, a surprising number of neophytic helicopter projects have been foredoomed by failing to develop adequate terminal facilities. In contrast to the popular conception that these man-made humming birds can descend and rise almost vertically from restricted or congested areas, they actually require essentially the same approach and departure clearances as conventional light airplanes. The actual touch-down pad may consist of almost any nearly level unobstructed surface area sturdy enough to accommodate the alighting gear, although winches and external freight may obviate even these requirements to a certain extent.

It is in this critical field of marginal reserve performance during loaded approach, landing, hovering and departure that the inherent limitations imposed by air density are felt most strongly. No one should contemplate using helicopters without a full understanding of the effects of density altitude on performance. Any increase in temperature or operating altitude results in a loss of lift and power in unsupercharged models. This undesirable feature cannot be overcome without compromising already limited performance characteristics through drastic reduction of the disposable load. Additional provision of adequate communications, servicing, and fire and crash protection are considered a must for all base heliports. The problems encountered in future exploitation of conventional helicopters will continue to be compounded so far as foresters are concerned by this reduced performance on hot summer days in the mountains. We have come a long way since the intrepid pioneers first operated 175 hp helicopters at 10,000 feet density altitude with 100 pounds payload. Now a 50 per cent increase in conventional power permits the same basic aircraft to handle three times this load easily under similar conditions. The impending advent of newer power packs, including superchargers, turbines, and reaction motors promises to extend these capabilities another 50 per cent in all classes of rotorcraft with greatly increased safety.

Climb-Out

So far, this discussion has outlined the steps necessary to get a helicopter program off the ground. If you are still on board, we will proceed with our climb out, during which some of the pertinent accomplishments of the past decade can be viewed in retrospect. A few of the more interesting achievements that have resulted from helicopter activities on the West Coast since their introduction 13 years ago include the massive airlifts, shuttling large groups of men, sizable logistic support missions, and greatly intensified aerial reconnaissance, primarily aimed at improving fire suppression methods, which of course are of mutual import to loggers. Actually, a breakdown of these activities shows 47 per cent of the flying in the airlift category, 8 per cent for hauling supplies, and 13 per cent for looking around. Tactical employment of helicopters on fires has grown recently to about five per cent of the total, and these promising services are slated for continued expansion. For example, spraying chemical dessicants onto fuels in a backfire or slash disposal area and subsequent firing out by fanning the carefully placed grenades offers new advantages for improved control of this critical mass fire maneuver. The use of plastic helitanks for direct chemical attack on fires, plus laying fire hose from airborne trays and other special accessory devices, is rapidly being adapted to fire use throughout the country. Specially trained and equipped helitack crews are currently taking their places alongside the vaunted smokejumpers for improving initial attack methods on remote fires. An additional seven per cent of these diversified specialties includes activities such as rescue and quick evacuation of distressed persons, specialized training, and the employment of other special devices including various cameras, winches, cargo pods, wire reels, and so forth. All of these services are easily adaptable to other forestry uses, which now comprise nearly 20 per cent of all forestry helicopter flying in our area. In actual practice, it has been conclusively demonstrated that the lessons learned from the large-scale employment of helicopters on fires can pay handsome dividends from the benefits to be derived through adaptation of infinitely better methods to other phases of modern forestry. Only a short time elapsed after the initial employment of rotor-wing aircraft on California fires until these same experienced crews and equipment, employing newly approved accessories, were effectively engaged in large-scale aerial surveys, plantation baiting, reseeding of burned areas, spraying for insect control, and type conversion projects. Of special interest in this type operation were the practical experiments aimed at penetrating timber canopies with granulated pesticides. This system successfully altered the surface ecology of sites slated for treatment by eliminating undesirable understory species not otherwise susceptible to aerial applications.

Right from their inception, great progress was made in the advantageous

employment of helicopters for improving engineering methods. Close visual survey techniques advanced to the point of preparing the initial photogrammetric surface controls quickly by bump-hopping geodetic crews throughout the initial pioneering and reconnaissance stages. Helicopters have further revolutionized delivery of construction crews and materials into unalterable or otherwise inaccessible areas without risking costly delays resulting from impassable surface conditions. One of the most interesting illustrations of this service is the airlift placement of beaver colonies into selected areas where they early strive to uphold their reputation as the best dam builders and loggers in the business. Another excellent example of this type of service was the winter construction of a transmission line wherein helicopters delivered the metal tower components, lifted partially assembled segments into place, towed the drag lines over the cross arms and across the long spans, and then performed the routine inspections without requiring any construction of the traditional power line access road, with its perennial maintenance problems.

Cruise

And now as we start to level off, it will be well to recall again that the current operations that are being discussed are for the most part carried out by specialists in the field of helicopter operations rather than by resource managers who may have established an incidental helicopter service unit. In too many instances where this system has not been adopted initially, near disaster has resulted. And so, while giving credit where it is most deserved, it is our strong recommendation that foresters initially avail themselves of the vast experience gathered by reliable helicopter operators rather than accept the risk themselves.

From the vantage point of our cruising altitude, we can now review the significant accomplishments of the last decade objectively, and apply the knowledge thus gained to current and future operations. We have seen how helicopters have been used extensively as a time-saving method for transporting men and equipment into remote or otherwise inaccessible areas, and in various search procedures.

Until recently, high altitude coupled with warm temperatures seriously limited the scope of available operations, and completely restricted some higher spots in the West. With the advent of newer sources of power, these problem areas have been greatly reduced until no spot on the surface of this continent can claim immunity to close helicopter surveillance. It is my pleasure to pass on the first authentic report confirming one of the most significant breakthroughs in the history of helicopter services to forestry. It comes from a western forest where we are currently evaluating the performance of a contractor's turbine-powered light helicopter. This fabulous machine has far surpassed all of its predecessors in every department except for prolonged intensive reconnaissance missions at lower levels. It has just completed 50 hours of operations above 12,000 feet density altitude with maximum permissible gross loads, which means at least a 600 to 800 pound short-range pay load, even at extreme altitude.

Bombs Away

With the timely realization at hand that current operating restrictions can and will be lifted, we now have today's objective in view, so let's go into a shallow orbit and see just how these modern tools can help resolve some of the logger's dilemma.

Surely the transportation of pole stock, which has been repeatedly accomplished successfully for nearly 10 years, will advance to some form of aerial logging. The rigging of high-line systems falls into the same category as stringing other forms of wire. Using helicopters to free log jams by towing, blasting, or even accelerating ice-melt with dark salts is highly probable. In fact, this towing capability appears especially favorable for loggers since the method utilizes well-established tugboat-type features wherein a large quantity of fluid or gas is displaced by a slowly moving rotor, which makes possible the easy transport of cargoes many times larger than the vehicle is capable of carrying directly. A seven-ton helicopter has actually towed a 300-ton barge across the Gulf of Mexico repeatedly.

A current shuttle project known as "helitug" may contribute significantly to logging engineering techniques of the future. As already conceived and put into operation experimentally, small helicopters can now transport disposable cargoes from six to ten times their carrying capabilities on pallets that are partially supported through the buoyancy of attached balloons. Since this system is inherently suited for shuttle work only, these future logging trains will be able to carry special gear and even compost stock back to the operating areas during deadhead trips.

Helicopter support for management photography extends literally from the ground up. It can hardly be surpassed as a stable platform for oblique or vertical stills scaling up to 1:5000, and it can just as easily carry TV scanners into any operating area. It will surely come into more use for preparing ground controls for the ultra-high altitude aerial photo coverage of the future, which will accurately record undistorted timber inventories on infra-red film exposed above 100,000 feet altitude.

Another use of helicopters for harvesting large, breakable trees such as our giant redwoods will be to serve as a platform from which parachutes can be attached near the crown to ease these valuable giants into their felling beds without costly breakup. As originally conceived, the parachute package was suspended from a small captive balloon, but this method has now been superseded by a better concept. This new system proposes that a parachute capsule, including a carbon dioxide charge which is actuated electronically, be attached to the top third of the tree so that it will trail free behind the falling trunk. Actual attachment can be done either by an aqua gun or directly by a man suspended from a hovering helicopter. As the top gains momentum, an operator in the helicopter or on the ground fires the air bottle electronically and thus deploys the parachute canopy and slows down the rate of descent of the entire trunk in a manner similar to that currently used to shorten the landing roll of jet aircraft.

The very real problem of the immediate future appears to stem from progressive requirements to harvest substandard tree crops in accordance with intensively managed plans. The common talk about efficiently utilizing more of the yield from thinnings, partial cuttings, and other special timber processes depends primarily on how well that material can be gotten out of the forest. In addition to solving supply problems by opening up remote pockets of virgin timber and harvesting over-mature stems, some organizations are already getting from one-third to one-half of their current timber volume from careful thinning, which further increases the productivity of the residual stands.

Without looking too far ahead into the future of the forest industry, we can visualize almost unlimited prospects and tangible profits accruable from the judicious use of helicopter services soon to be available, even though such services should never be considered as a panacea for all of the difficult transportation problems. Surely the trees grown from here on out are going to be stronger, healthier, and much faster growing than their predecessors, thanks in no small part to airborne reinforcement with growth hormones, such as giberellic acid, and modern pesticides.

Recent evidence from overseas indicates that 10 to 15 tons has been carried above 20,000 feet by a turbine-powered helicopter of apparently conventional configuration.

How we use the helicopter to log our future superforests depends in large measure on the groundwork laid during the next decade. It is the firm conviction of many who are associated with this type operation that traditional logging transport methods will be largely outmoded within the next 25 years on all but the most easily accessible cutting-cycle areas. Specifically, there may no longer be any felling of timber or even the use of saws. Instead, trees selected for harvest will be indicated by radioactive tracer and either separated from a ground-level stump by a cutting ray or possibly pulled up intact by giant logger-type helicopters, the prototypes of which have already passed the design stage and are now undergoing testing as flying cranes. Hooks and chokers will be set electronically by an airborne controller through the use of remote television scanning; the entire tree will be lifted from its site and carried, roots, trunk, limbs and all, to the mill landing. Thus, all tree components will be brought to one spot for most efficient utilization. One of the most important features of this removal from the forest is the near-perfect elimination of fire hazards and insect breeding environments now prevailing in slash residue. The remaining trees will then be allowed to develop and ripen in healthy surroundings. The virtual elimination of costly damage to reproduction plus more complete soil usage is another valuable contribution.

These proposals can largely eliminate the wasteful methods still blighting the woods-operation phase of modern logging. Since there will be no limbing or bucking of trees to add duff, refertilization can be economically completed through the use of reinforced wood residues, mainly from the bark. Through this helicopter logging system, areas otherwise inaccessible will be opened to harvest for posterity.

Mission Accomplished

The age of vertical take-off and landing (VTOL) aircraft has arrived, and it behooves modern foresters at all levels to become fully cognizant of present capabilities and future potentials of this veritable magic carpet.

And now, having covered enough ground on this trip, our flight plan calls for a speedy return to the base where we can replenish our fuel and oxygen supplies for similar missions scheduled to keep foresters interested while awaiting the great day when forest products are delivered FOB Chipper, Cheaper by Chopper.

Helicopters in Logging Operations[1]

LLOYD SLOAN

Manager, Sales Engineering, Vertol Aircraft Corp., Morton, Pa.

Twin-turbine helicopters soon to be available commercially have a definite application in logging operations where rough terrain or high altitude make surface haulage impractical. With currently available single piston engine models, the direct operating cost of hauling fir logs over a 3-mile radius from 2000-foot altitude is $16.75 per Mbf. This would drop to $14.30 for the initial turbine model, with further cost reductions anticipated.

THE POSSIBILITY OF USING HELICOPTERS to extend logging operations into presently inaccessible timber resources has aroused many inquiries among lumbermen as to the capabilities and operational cost of currently available transport helicopters.

A preliminary investigation has indicated that, while the present single-engine transport has a lifting capability (5,000 pounds maximum) approaching the minimum acceptable log size, the nature of the helicopter logging mission strongly suggests the use of multi-engine models (such as the Vertol 44 retrofitted with either 2 GE T–58 or Lycoming T–53 turbine engines). Not only does the lifting capacity rise to a more acceptable value (over 6000 pounds) but the safety of the twin-engine feature in operations over the typically rough terrain involved would be invaluable, not only in reduction of hazards but also from the economics of hull insurance. With twin turbines, an engine failure would only require that the pilot drop the log and proceed on the other engine to the nearest practical landing area.

For this reason, the following brief study emphasizes the application of the turbine helicopters that will be available by 1960, prototypes of which have already been flying for some time in military configurations.

A prototype of the twin-turbine Vertol helicopter, here being flight-tested for the military.

[1] Presented at Session VII, Helicopters in Logging, FPRS Twelfth National Meeting, held October 22–27, 1958, in Madison, Wis.

Table 1.—DIRECT OPERATING COST, VERTOL 44A
(See text for minor revisions.)

		COST/HOUR OF UTILIZATION ($/FLT. HOUR)			
COST ITEM		800 HRS.	1000 HRS.	1500 HRS.	2000 HRS.
FLIGHT OPERATIONS	Pilot	20.00	20.00	20.00	20.00
	Fuel & Oil	22.00	22.00	22.00	22.00
	Insurance	34.88	27.90	18.60	13.95
	Sub-Total	76.88	69.90	60.60	55.95
MAINTENANCE & SERVICE — LINE	Labor	11.05	11.05	11.05	11.05
	Parts & Material	2.25	2.25	2.25	2.25
OVERHAUL — AIRCRAFT	Labor	11.50	11.50	11.50	11.50
	Parts & Material	12.87	12.87	12.87	12.87
OVERHAUL — ENGINE	Labor	.77	.77	.77	.77
	Parts & Material	4.17	4.17	4.17	4.17
	Sub-Total	42.61	42.61	42.61	42.61
DEPRECIATION	Aircraft & Engine	55.80	44.64	29.76	22.32
	Rotable Spares	13.95	11.16	7.44	5.58
	Sub-Total	69.75	55.80	37.20	27.90
TOTAL COST ($/HR.)		189.24	168.31	140.41	126.46

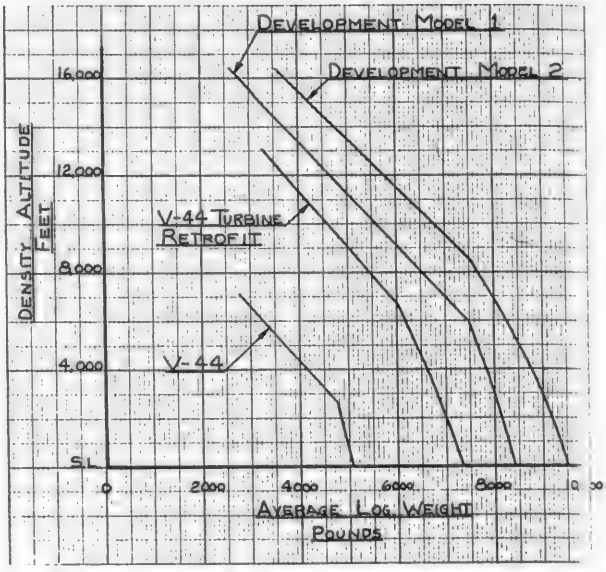


Fig. 1.—Average log weight vs. altitude (based on fuel for one hour of operation).

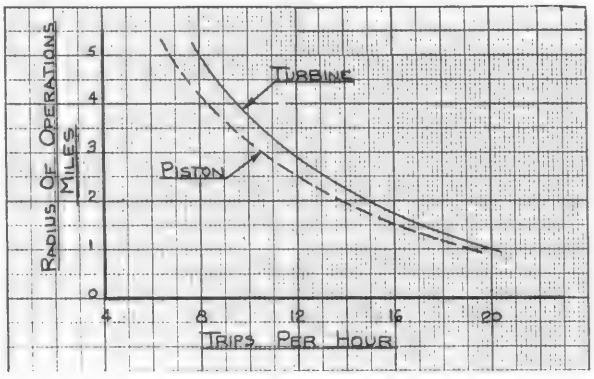


Fig. 2.—Trips per hour vs. radius of operation.

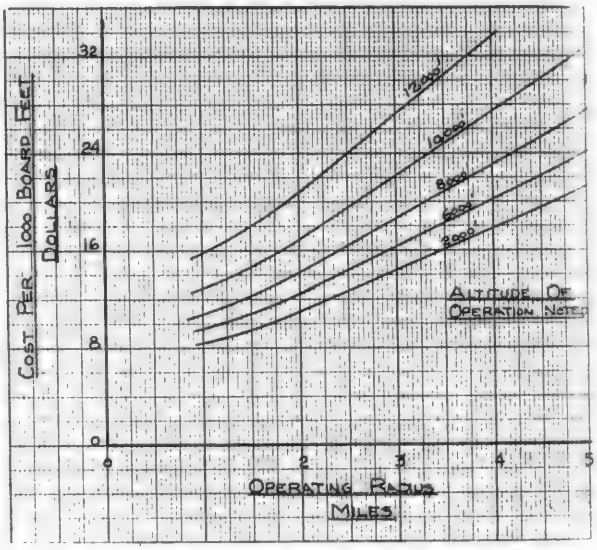


Fig. 3—Cost per 1000 board feet vs. operating radius (based on Development Model No. 1).

Average Log Weight vs. Altitude

Fig. 1 shows the load-lifting capabilities of the present single piston-engine helicopter together with those of the multi-turbine helicopters that will become available commercially in the next two years.

The log weight is based on the average weight of the helicopter during a one hour logging operation, and is based on the assumption that the log must be picked up when the helicopter is completely out of ground effect.[2] (If terrain permitted operation with the wheels even 20 feet off the ground, an increase of 350 pounds in log weight would result).

[2] Ground Effect: The additional lift gained by the helicopter when near the ground, caused by the rotor downwash building up under the helicopter faster than it can escape.

Radius of Operation vs. Number of Trips Per Hour

Fig. 2 is presented to show how many round trips can be made for typical distances over which logs might be carried (that is, from logging site to a pond or river). Although the turbine helicopters are inherently faster than the piston type, this curve is not greatly affected except at the greater distances. This is shown by comparing the solid with the dotted curve, the latter representing the piston engine. A representative elevation of 2000 feet is used, and an allowance of 10 minutes per hour is included for refueling and minor servicing, (oil level checks, and so forth).

The direct cost of operating Vertol helicopters was computed with quite good accuracy, and these costs are shown in Table 1. Subsequent operations under commercial conditions indicated that some changes were in order, primarily under the categories of engine overhaul and depreciation. Increased overhaul costs are approximately balanced by other reductions, however, so that the revised Total Cost figure at 2,000 hours is the same, and at fewer hours is somewhat less. It should be pointed out that direct operating costs include only the operation of the helicopter itself, and do not include such fixed expenses as hangar rental, clerical and office work, or any field costs such as cutting.

For logging operations, it may be expected that the helicopter will be

operated at maximum utilization, limited only by the hours of daylight available, the weather, and possible seasonal aspects of the logging operation. In any event, utilization on the order of 2000 to 3000 hours annually may be expected, so that the 2000 hour column may be used conservatively. Thus a representative hourly direct cost would be about $126.00 per flight hour for the currently available 44A piston-engine helicopter. The turbine helicopters when first available commercially will have costs approximately $50.00 per hour higher. However, the increased capacity and multi-engine safety characteristics will reduce the net logging cost. Ultimately, the light weight and basic simplicity of the turbine will result in an appreciable reduction in the initial hourly cost, as overhaul tours are increased and price of the turbines and components are reduced.

Net Logging Cost

Combining the above information, the following example can be used to determine the logging cost.

Assumptions:

1. Logging site is at an elevation of 2000 feet.
2. Site is 3 miles from river or pond.

Piston Engine:

From Fig. 1, it is seen that an average log weight of 4800 pounds may be carried, and from Fig. 2 a value of 10½ trips per hour is obtained, so that on an hourly basis, an average of $10\frac{1}{2} \times 4800$, or 50,400 pounds of logs can be carried.

If it is assumed that the logs are green fir at 40 pounds per cubic foot and that there are 6 board feet per cubic foot, the hourly load of 50,400 pounds is $50{,}400/40 = 1260$ cubic feet, or $6 \times 1260 = 7560$ board feet.

From the cost table (Table 1) at an annual utilization of 2000 hours, the hourly direct cost was $126.40 or a hauling cost of $126.40/7.560 or $16.75 per 1000 board feet.

Turbine Engine:

With the same basic assumptions, it can be seen that the first available twin-turbine logging helicopter (retrofit of the piston-engine model) will handle an average log weight of 7000 pounds (Fig. 1) at 2000 feet. From Fig. 2 it will be found that the turbine can perform 11.7 trips per hour at the example radius of 3 miles. Thus the hourly weight of logs is 11.7×7000 or 82,000 pounds.

Still assuming the logs to be green fir, the turbine helicopter will haul $82{,}000/40 = 2{,}050$ cubic feet per hour or 12,300 board feet per hour.

Since it was expected that the first turbines would initially cost more to operate, it was stated that the direct cost would be about $176.00 per hour for the 2000-hour utilization. Thus the hauling cost for the turbine would be $176/12.3 = \$14.30$ per 1000 board feet. Results are summarized in Fig. 3.

The more advanced turbines with their increased capacity and substantially the same hourly cost will further reduce the logging haulage cost by as much as 30 per cent due to capacity improvement, and the further cost reductions that may be expected with continued development of the turbine installation.

A 3200-pound pole on a 60-foot cable is maneuvered easilly by this Vertol 44. Ballast loads of 5000 pounds have been carried by this model.

Conclusion

From the above study, Fig. 3 has been drawn to show the cost per thousand board feet versus radius of operation for practical elevations. This graph is based on the Vertol 44 retrofitted with two-turbine engines in place of the present piston engines. This represents the first stage in multi-turbine development in helicopter logging operations.

When Can We Log by Air?[1]

CARL AGAR

Vice-President of Research and Training, Okanagan Helicopters Ltd., Vancouver Airport, B. C.

Cargo of all types is being moved by air where mechanical ground equipment is inoperative or where the economics of road building and time saved are in the helicopter's favor. Its future in logging will not be as we see them today. Rather, logging helicopters will be of a simpler construction, after the style of a flying crane: a horizontal frame, a set of blades, multiple-engine, and an operator's cabin with a bird's-eye view.

WHEN CAN WE LOG BY AIR? It was in 1948 when the use of the helicopter was in its infancy that we were first asked this question by a logger in British Columbia, and at that time the prospect of logging by air was a long way off. However, as the helicopter's versatility increased, the same question has been asked dozens of times.

Since we were first asked "When can we log by air?" a decade has passed and larger and more versatile helicopters have come into practical use. In fact, the time has come when the question rightly demands some analysis, because the helicopter industry itself is eagerly looking forward to the production of a helicopter that may be best described as a "flying crane."

Some men remember when logging was done with horses and oxen. Since that time, equipment has been developed that 50 or 60 years ago was beyond the comprehension of ordinary men. It took practical dreamers to do it, and the achievement has been re-

[1] Presented at Session VII, Helicopters in Logging, FPRS Twelfth National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Carl Agar developed his flying ability primarily during World War II, and in 1947 was instrumental in forming the Okanagan Helicopter Group, which this season will be operating 56 helicopters. Agar received the McKee Trophy (Canadian) in 1950 and the W. J. Kossler Award (U. S.) in 1954; both are coveted awards for contributions to aviation.

Fig. 1.—With the advent of multi-turbine, "flying crane" helicopters, full trees may be carried in a manner similar to that used with these 60-foot poles.

markable. Unquestionably there were scoffers in the past, so that it ill-behooves anyone to ridicule such a thing today as logging by air, when we are confidently talking about flying to the moon!

The development of the helicopter has been similar to that of logging equipment, it has been going on for decades, but this aspect of the helicopter will be left to the representatives of helicopter manufacturers who are also participating in this panel.

The Forest Industry's Use of the Helicopter to Date

A variety of forest products have been transported by helicopter, but the surface has merely been scratched. While there have been numerous applications of this versatile transportation vehicle in the forestry field, progress has not been rapid, partly because the industry and the helicopter operations seem to be a little slow in becoming acquainted, but primarily because of the lack of a really suitable utilitarian machine. A start has been made, however, and there is a realization that time will solve the problems; in the meantime, we are all gaining experience that will be invaluable in the future.

In Canada, helicopters entered the forestry field with timber cruising and forest spraying. While neither of these have been carried on extensively, timber cruising by helicopter is increasing as forest surveys are conducted on increasingly larger scales. In 1954, 2,000,000 acres were surveyed. A crew of 40 personnel were located, moved, and supplied by one helicopter. Five-hundred hours were flown in four months. The survey was completed in one season by helicopter, whereas done by ground methods, it would have taken four seasons. This year, four helicopters will be engaged by the B. C. provincial government exclusively for air coding of forest areas.

Forest seeding is another task for which the helicopter is ideally suited. Seed, specially treated with poison and coated with aluminum paint, is metered out over the area involved and has proven successful. In the Pacific Northwest, many thousands of acres are seeded each year in this fashion, a governing factor being the availability of seed.

Prefabricated buildings are commonplace helicopter cargo now, and these include bunk- and cook-houses. Lookout stations and rangers' cabins are also being delivered by helicopter where no road is available. In the northwest, the location of stations are on mountain tops. Cargo involved in such moves includes timbers, lumber, plywood, shingles, all the necessary tools, and so forth. In 1949, the lumber was kept to short lengths, that is, eight to ten feet. As experience was gained, the length was increased to 16 feet with some lengths going to 20 feet when necessary. But the larger helicopter's arrival changed this again, and 20-foot material became commonplace. Today, loads of lumber delivered by sling are quite usual. This of course is in areas where no other form of transportation is feasible. As time progressed, poles and logs were moved as required, and in 1956 hundreds of trips were made with "A"-frame poles up to 45 feet in length.

Fire-fighting by helicopter has been going on for years, but on a fairly small scale; nevertheless, the value of the helicopter has been proven in effectively moving personnel and equipment to and from fire areas.

The Possible Application of the Helicopter in Logging Operations

We have mentioned that the present helicopters have played some part in the fighting of forest fires, but a larger helicopter, along the lines of a flying crane, would provide a more realistic method of fighting fires from the air. The type of machine we envision, capable of carrying tons of chemicals and capable of ejecting them from high-pressure pumps, will be more realistic. With such a machine, a fire could be doused quickly when in its initial stage, or at least effectively checked until ground forces and equipment can be brought to the scene.

However, the main job of work it is proposed that the flying-crane type of helicopter would do in logging operations is the removal of timber from felled areas, thus replacing all types of equipment that are presently being used on the ground for such purposes. This helicopter would lift the logs from such areas and deliver them to the point where other forms of transportation could take over. Where water was the final method of transportation, delivery would be to the desired water location, and in other cases it might be to a railhead or to a trucking road. The distances that these delivery points are from the logging operation will have a direct effect on the economics, and only time will tell what the break-even point will be in the length of the haul in miles. A start might be made on small pockets of timber left behind in logging operations due to the inaccessibility at present. The timber might be good but also might be reaching maturity. In all likelihood, the value of logs per pocket would not justify a road. However, experience in conducting this type of operation would be gained rapidly; moving from pocket to pocket with changing terrain would provide a wide variety of conditions that would soon provide an indication of the practicality and the economics. It is possible the flying crane might be the answer to getting out certain valuable types of timber presently inaccessible.

Conclusion

When can we log by air? The helicopter, an accepted short-range transportation vehicle, operating from zero to airspeeds of roughly 100 mph., we believe is within the realm of being capable of moving logs at speeds from 40 to 75 miles per hour. The helicopters available today, however, are a far cry from the type needed to permit us to log by air. We all have flown over or gone through large logging operations, and are aware of the size and weight of the timber and also the ruggedness of mountain slopes. We also are aware of the size and power of logging trucks and ground equipment required in the forests. In many areas, logging is being carried on farther and farther away from established roads and new equipment is being developed to deal with this situation. Portable spars and grapplers are playing their part, but logging is getting tougher and tougher as stands become more inaccessible.

Methods of logging have improved since the days of oxen and horses; machinery has been developed by men with practical imagination. Therefore,

Fig. 2.—The morale value of having helicopters available for emergency evacuation from remote areas is highly important in forest operations.

it is no surprise to find similar men looking to a type of helicopter that seems ideally suited to the job. A helicopter can hover, ascend, and descend vertically, as well as fly in any direction; it can pick up and set down loads, without landing. But what are the requirements of a helicopter that will permit logging by air? Here is a helicopter operator's viewpoint on this question. It is not necessary to go into the minor details, but there are certain basic fundamentals that must be embodied in this new vehicle if it is to work satisfactorily on what we believe to be one of the toughest jobs in the world, and this, of course, rests in the hands of the helicopter manufacturer; in other words, he must produce the tool to do the job.

While it may not be an easy task to design and produce a flying crane that will, among other things, be capable of logging by air, there is no doubt that the flying crane will become a reality. On the basis of my experience and knowledge of helicopter operations, I will set out what I consider are the basic requirements. Its design must be as simple as possible, in order to reduce maintenance, engineering, and tooling costs, and keep the economics within acceptable bounds. It must be foolproof in order to maintain required schedules. It must be multi-engined or have an infallible source of power and, indeed, a surplus of power that will allow the crane to fly with ease while picking up logs sawed to length, more-or-less regardless of weight. Sufficiency of power of course will enhance the safety of the operation, and it must be realized that the terrain over which the flying crane will be operating will be a maze of logs and stumps with no place for emergency landings. The possibility of a power failure causing a forced landing must be so remote as to be considered beyond the realm of possibility. Three engines might be desirable; at any rate, it should be capable of flying with one engine inoperative.

The pilot's cabin must have unlimited visibility all around. There may have to be two pilots, facing in opposite directions. Practical study must be applied to the design of the pickup tongs to produce a simple and workable arrangement. The tongs must be flawless in their operation 100 per cent of the time to ensure the safety of the crew and the equipment. Such a device may have to be hydraulically controlled by the operator in the air, because men on the ground would be vulnerable. Consideration should be given to a powerful winch in order to cope with various types of topography. The flying crane and the pickup gear must function so perfectly that the moving of logs would be almost as routine as though done by a ground crane. These factors, at least, we feel should be embodied in an aerial crane, if it is to be practical for logging purposes.

In considering a helicopter such as described here, manufacturers must keep in mind that a handsome appearance is not important; we believe what is finally designed will *look* just like a flying crane. They must also keep in mind that equipment built for any aerial operation must be designed on the premise that the possibility of losing equipment or personnel is so remote that it is considered nonexistant, and for this reason the manufacturer must appreciate the safety factor involved to assure continuous safe operation. There is no use of hauling out, say, 9,872 logs and then losing the crew and equipment because the safety factor was based on the law of averages. Mishaps should occur only as a result of what may be termed long outside chances.

The flying crane described here will not likely be the one used initially. A smaller version, one capable of handling the shorter logs, will likely appear first to prove or disprove its practically and indicate the economics. The idea may seem radical to some, but the achievement would be colossal. We must not get our thinking out of focus by imagining all of the difficulties. Actually, moving logs by air is really quite simple compared to flight to the moon!

It seems as though the answer to the question rests not altogether on whether a flying crane can be designed with sufficient built-in ruggedness to permit is to do one of the roughest jobs in the world, but whether such a machine will fit the economy of the lumber industry. The helicopter manufacturer can say if such a machine can be designed, but only after he has thoroughly reviewed what logging really entails. The design engineer cannot imagine what is involved from his draft board. He would be well advised to go to the Pacific Coast to get a realistic appreciation of the gigantic size and weights of logs, and at the same time obtain a realistic picture of the helicopter operator's problems as they relate to terrain. When he has first-hand knowledge of these two things and has seen the ground equipment the flying crane should be designed to replace, he will appreciate his task and at the same time realize why we say: "The achievement will be colossal." Designers today can do almost anything, but they are very wise in their predictions; they know that what they achieve must be practical to be successful. When they have reviewed the implications of logging by air, they can give us an indication of what can be expected in the way of equipment and cost. Then the logging interests and the helicopter operators must sit down and determine whether or not the ante is too high to stay in the game. Only time will tell; or should we say, only time and dreamers?

Helicopters for Forest Operations[1]

J. G. TOWNSEND

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The variety of practical applications for helicopters in various forest operations are illustrated by selected examples from the experiences of this Canadian firm. Some rough cost comparisons are presented.

AFTER THE FIRST WORLD WAR, the now almost legendary bush-pilot, with his float-equipped airplane, solved to some extent the transportation problems of the trapper, the surveyor and the prospector; but nearly three decades were to elapse before the canoe and the dog-team were to be seriously challenged as the only practicable means of travel in the bush.

History

After the Second World War, Canada enjoyed an unprecedented era of economic expansion. Gold had taken a back seat to uranium in the prospector's affections, and copper was more eagerly sought after than silver, but the industrial world was hungry for minerals, and the advent of geological and geophysical survey by air had disclosed vast new potentials of mineral wealth in the inaccessible bush country of northern Canada. In 1947, Spartan Air Services commenced operations with a small fleet of fixed-wing aircraft. The early operations were exclusively in the field of aerial survey, but during the next three years they were rapidly expanded to include geological and geophysical survey work.

By 1947, the helicopter was beginning to make it's mark in commercial aviation. In the United States, a number of jobs had been undertaken with promising results, and as a tool for fighting forest fires, the helicopter had proved itself an immediate and unqualified success. It rapidly became apparent that a helicopter service would provide an excellent complement to fixed-wing services, and in 1950 the company purchased its first machine—a Bell 47D1—and commenced operations on field survey work.

The following year the fleet was increased to two, and by 1953, four machines were operating. These early operations were attended by some of the inevitable difficulties to be expected in a pioneering venture, but by the end of the 1953 season, we had gained sufficient experience and confidence in helicopters to face the future with optimism rather than apprehension. The future indeed was limited not by a dearth of working capital, nor by a lack of potential customers, but by a shortage of trained personnel. This problem has been with us ever since, and we have had to support a heavy program of pilot and engineer training. During our eight years of helicopter operations we have been working at—and sometimes almost beyond—our capacity on survey, geological exploration, and bush transport in general, so that the full potentialities of the helicopter in industry have by no means been fully exploited. This applies particularly in respect to the forest products industry.

Experience

In attempting to describe my company's experience in the field of helicopter transport, it is difficult to know where to begin, and impossible to know where to end. The particular merit of the helicopter is vested in a degree of versatility never previously approached by a vehicle of any description, and it would be no exaggeration to say that the application of the helicopter to any problem of transportation is governed almost entirely by the gross weight of the materials involved, and the ingenuity and imagination of the operator. We have, at one time or another, carried everything from the corpse of a frozen trapper, to—quite literally—the kitchen sink. Indeed, we have carried such a variety of loads in such a diversity of geographical situations that a catalogue would be intolerably tedious; so instead, two or three typical examples will be offered of the ability of a small helicopter—the Bell 47D1—to tackle a big job; and then a brief comparison of costs will be made. Comparisons are said to be odious, but in the helicopter business we find that this is seldom the case.

The Selection of a Site for a Forest Look-Out Tower, and the Subsequent Lift of Men and Materials: The initial selection of the site was accomplished by an official of the Ontario Department of Lands and Forests, who was flown by helicopter in a pre-selected vicinty. The helicopter was hovered 100 feet (the height of the tower) above the summit of a hill, turning slowly on its axis to allow a careful check of the visual coverage over the surrounding terrain. This procedure was repeated over several hills until the most promising location had been determined. The helicopter then landed, and a ground check was carried out. This proved to be satisfactory, and the helicopter left the area to work elsewhere, while preparations were made for the airlift. The closest and most convenient base was on an abandoned tote road, which ended about 10 miles from, and some 800 feet below, the tower site. From here on the following week, a crew of four men, together with a gas-driven rock drill, lumber and tools, was flown to the top of the hill, and they completed the erection of the forms for the concrete foundations on the first day. On the second day, the concrete was mixed in a mechanical cement-mixer at the base, where sand, gravel, and water were readily available. The concrete was then flown in buckets on the side racks, and poured directly into the forms. Because of their weight and stability, the buckets did not need to be tied down, and this phase of the operation—the pouring of the foundations for a steel tower, 100 feet high and weighing 10,000 pounds—was completed in five hours.

During the next two days, the steel for the tower, the tower cabin, and the materials for the tower man's living quarters—a total in weight of 28,000 pounds—was lifted to the top of the hill, and the construction crew of five men with sufficient food for two weeks was left to complete the job.

[1] Presented at Session VII, Helicopters in Logging, FPRS Twelfth National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: J. G. Townsend's aviation experience dates back to 1939. During World War II he flew Sunderland flying boats for the RAF, and after the war obtained a B.Sc. in civil engineering from Queen's University. He worked part-time with Spartan while attending the university, and joined Spartan's embryo Helicopter Division full time in 1950.

Fig. 1.—Lower fuel consumption of the smaller helicopters makes them more economical for rapid movement of light loads such as replacement parts, and for emergency evacuations.

The total time involved was four working days, or 27 hours and 20 minutes of flying time. In this time a total of 36,700 pounds, in men and materials was moved. The official in charge of the project estimated (in the light of 20 years of experience) that 12 men would have been required to work for three months to accomplish the transport phase of the operation—that is the move from the end of the road to the top of the hill. At a salary of $10 a day per man, the salary bill alone would have amounted to $10,800; and in addition to this there would have been a substantial food bill. Compare this to the cost of the helicopter: approximately $2700, plus $200 for salaries and a negligible food bill. In other words, a saving of nearly $9000. In industry, where time is money, the saving would be very much more significant.

The Selection of a Route for a Development Road to the Site of Prospective Logging Operations: A tentative route was marked in on a photo-mosaic of the area, and probable helicopter landings were selected. The distance involved was approximately 24 miles through heavily timbered country.

The engineer-in-charge was flown over this route, and several disadvantages of the initial selection were readily observed and amended. A return run was made for detailed observation, and the helicopter made numerous landings to allow the engineer to examine possible physical obstructions, such as water, swamp, or rock outcrops.

In one working day, or three hours of flying, the job was finished to the complete satisfaction of the engineer-in-charge. This compares to approximately 10 days of work on foot, with the attendant expense of setting up and supplying a bush camp.

The helicopter costs in this case, including two hours for ferry time to and from the area, were $300. There are no exact figures to offer on the costs of a preliminary ground survey of this nature, but it would be considerably in excess of $300.

The Suppression of Six Lightning Fires in a 2000 Square Mile Area of Valuable Standing Timber: The helicopter was based in Sudbury, Ontario. The fire hazard was "extreme" and a number of electrical storms had been active throughout the previous night. By noon a strong and gusty wind was blowing, and smudge reports began to come in from the look-out towers in the district. Between 12:30 and four o'clock, the helicopter had spotted five crews of fire-fighters (two men to each crew), together with basic fire-fighting equipment—water packs, axes, shovels, sleeping bags, and enough food for two days.

All these fires were simple, typical lightning fires: that is to say they were confined to one tree, and they were easily controlled. But the sixth fire had spread to an area of six acres, and required eight men with pumps, hoses, and associated equipment, together with camping gear and food for several days. These were delivered before night-fall, and the fire was brought under control during the night.

In all cases it would have required several hours of hard slogging through the bush to reach the fires from the nearest access. Hours during which the wind was gusting up to 50 miles an hour, and early suppression was a vital factor.

The cost of the helicopter in this case was $650, and again no exact costing comparison will be made. All or any one of these smudge fires might, with the conditions prevailing at the time, have developed into a large and extremely costly affair. A fire of 10,000 acres would cost the taxpayer in the neighborhood of $100,000, and this would cover only the expense of fighting the fire, not the damage to the standing timber.

These examples illustrate, very briefly, some actual experiences we have had with helicopters in the forestry industry. They have been offered without a detailed costing, merely to indicate that the prevailing idea that a helicopter is a costly tool to hire is a misconception.

Uses of the Helicopter in the Forest Products Industry

Now some of the potential uses of a helicopter in the logging industry will be suggested with emphasis on the fact that these are merely some suggested uses—the potential is almost infinite.

The helicopter is a superior vehicle for conducting a forest inventory, and for timber cruising. At the same time, areas of diseased timber can be readily spotted, and in most cases a landing can be effected for ground inspection. Infected samples can be removed for laboratory analysis, and then if necessary the helicopter can be used to spray the infected areas with insecticide or herbicide as the occasion warrants. The vertical air currents set up by the rotor blades help to do a particularly effective job in spraying, by forcing the spray up underneath the foliage, as well as covering the top surfaces.

As a means of transport for supervisory staff on logging operations, the helicopter offers several readily apparent advantages, not the least of which is the effect a helicopter has on production. Indeed, the mere sound of its engine can exert a remarkably invigorating influence on an unenthusiastic lumberjack.

The helicopter can be used for the laying of, or the maintenance of, telephone lines, and for the repair and maintenance of transport and mechanical equipment.

The helicopter is an invaluable vehicle for the observation and control of log drives. It can be used to spot and help control log jams, to salvage beached logs, and to tow log booms. Water reservoirs and potential drive routes can be accurately assessed from a helicopter, and in addition to these tasks, the helicopter is always available for the day-to-day business of running a profitable logging operation: the delivery of urgent spares, the expedition of urgent engineering or management consultation, and the close

and constant supervision of cutting operations.

In the area of medical assistance and casualty evacuation, the helicopter has proved itself on so many occasions that further comment would be superfluous.

The suggestions outlined apply generally to the smaller transport helicopters, with a payload of approximately 450 pounds. We are now operating the large twin-rotor Vertol H-44 machines, with a payload of up to 5000 pounds. Large enough, in fact, to solve almost any problem of bush transport, but the latter will be discussed in connection with a forecast of future employment of large helicopters.

Forecast of Future Large Helicopters

During the past three years, a number of articles have appeared in the aviation journals prophesying the impending demise of the helicopter. The converti-plane, or vertical take-off aircraft—an aircraft encompassing the speed and range advantages of the fixed-wing airplane, with the hovering and vertical characteristics of the helicopter—will, they say, render the pure helicopter obsolete.

A variety of engineering approaches to the problem are being tried on both sides of the Atlantic, and it is reasonable to suppose that an aircraft of this description will make its appearance in commercial aviation during the next decade. In the meantime, however, one should feel safe in forecasting that the helicopter has a long and useful life ahead of it before it joins the Dodo.

A particular application is the use of the helicopter in the role of an aerial crane. The large helicopters now in operation are able to function very successfully in this capacity, and a number of machines are planned for the future with this particular role in mind. They will be powered by two or more turbine engines, and will be designed so that they can straddle a large cargo pod, or simply lift, as a normal crane does, loads of up to 20 tons.

The application of a helicopter of this nature to the problems of construction engineering are too numerous to mention here, but the possibilities in the logging industry are immediately obvious. A logging operation could be conducted deep in the most inaccessible country without the necessity for costly road development.

The complete operation—machinery, men, and materials—could be flown in by helicopter, and the logs could be flown directly to the nearest road or rail-head.

If the cost of conducting an operation might, at first, appear prohibitive, one should consider how much heavy ground equipment would be rendered obsolete, how many trucks, bulldozers, and graders would no longer be needed. To repeat again, experience has invariably proved that the helicopter is the most economical answer to transportation problems in undeveloped country.

Discussion

R. T. Haussman (U. S. Forest Service): Would Mr. Sloan please describe the job done by helicopters in transporting and planting power and communication poles in the Philadelphia area last winter after a severe ice and snow storm?

Mr. Sloan: I understand the poles were moved by helicopters, but they were not actually planted in position by these machines.

Mr. Kwiatkowski: In our operations in California, we planted such poles for several companies. In fact we planted close to 200 poles at varying altitudes (from 1000 ft. to 5000 ft.) and the photos which I have submitted were taken not of a single demonstration, but of actual work accomplished.

F. C. Simmons (N. E. Forest Experiment Station): I feel that the early use of helicopters will be to remove high-quality material. During the last eight or ten years, large quantities of diseased birch were not extracted from the wilderness area in Maine because of excessive road-building costs. It is my opinion that this material, worth up to $300 per M bd. ft., could have been effectively salvaged with helicopters, if they had been at their present state of development when this emergency occurred.

D. B. Turner (MacMillen & Bloedel): What is the effect of the up and down drafts in the mountains in British Columbia on the use of helicopters? Would these drafts preclude their use?

Mr. Agar: Downdrafts in British Columbia in certain locations would at times make it prohibitive to operate helicopters, because the downdraft flow of air under certain conditions would be too great for the capacity of the machine. Under these conditions, present-day helicopters could not operate with much of a payload and any surplus power.

J. Lupsha (Maine Forest Service): What is the effect of altitude on the lifting capacity of the machine?

Mr. Kwiatkowski: Generally, the greater the elevation the lesser the lifting capacity of the machine. It is somewhat dependent upon the type of engine in the machine, but it is fair to say that a present-day type of helicopter with a lifting capacity of 5,000 pounds at sea level could only lift about 4,000 pounds at an elevation of 5,000 feet. This is a difficult question to answer as many factors are involved.

Mr. Ferris: The application of the turbine engine has been an outstanding recent development in the manufacture of helicopters. This engine has the great advantage of having lots of power, and being relatively light in weight. Its chief disadvantage is its high rate of fuel consumption.

Mr. Sloan: The light-weight turbine engine makes it possible to design efficient multi-engine helicopters with greater lifting capacity and engine-out safety. Such helicopters are now flying and will become available for helicopter logging in about two years.

J. R. Ritchie (Wm. Milne & Co.): What is the expected life of the so-called rugged machine of the future?

Mr. Agar: By a rugged machine is meant one that is simple in construction, and I would expect its life to be at least 10 years under normal operation.

Mr. Kwiatkowski: I know of a helicopter operation in Los Angeles that in the past 10 years has logged 10,000 hours flying time per each individual machine (they have four of these aircraft) and they are still going strong.

H. J. Doyle (N. C. Forestry Assn.): Have you investigated the use of the one-man helicopter?

Mr. Ferris: Some small machines that carry one man are very useful in reconnaissance and inspection work. The small Hiller machine can only carry one man weighing 180 pounds and 40 pounds of luggage. However, I would caution against the use of small machines with tip jets. When one of the engines fails, the machine drops like a rock. All these one-man machines need qualified and well-trained operators.

Robert Olin (Potlatch Forests Inc.): Helicopters may be used effectively in forest spraying operations. In some cases they are superior to fixed-wing aircraft for this purpose.

Dr. Emanuel Fritz (Consultant): A number of loggers in the redwood region are halving and quartering logs prior to felling. This reduces the log weights within the capacity of a 4-ton lift machine. The job of quartering can be done in the woods. The quartering is advantageous to the sawmill. It is done, of course, with chain saws.

Evaluating Quality of Black Walnut Sawlogs[1]

W. W. KING

Staff Forester, TVA, Division of Forestry Relations, Norris, Tenn.

This study, conducted in cooperation with a commercial walnut mill, should enable timber growers and processors to buy and sell walnut with mutual understanding of its value. The paper contains an example of how to use the quality class system for developing a log pricing structure. It also includes instructions for applying the quality class rule.

BLACK WALNUT *(Juglans nigra L.)* ranks first in unit value among American lumber and veneer woods. TVA considers walnut as the top-quality hardwood species in the Tennessee Valley. Although walnut lumber accounts for only a small portion (0.3 per cent) of the Valley's hardwood production, its annual value is estimated at close to $750,000. It occurs generally throughout the Valley, and since it grows in mixture with other hardwoods, its presence in the forest is an added incentive for better woodland management.

Walnut, unlike most other species, can be sold on an individual tree basis. For this reason, it is highly profitable for the landowner to plant improved walnut varieties on the better soils. He, as well as the lumber producer, should know how to appraise the quality of this valuable forest tree.

Source and Kind of Data

All the study data were collected at the George E. Tomlinson Co. walnut mill in Winchester, Kentucky (Fig. 1). This operation centers around a six-foot, left-hand band mill and a 14-foot cable-driven, electrically powered carriage. The carriage is equipped with air-operated dogs. Logs are turned with an air-operated turner. Additional facilities in the over-all operation include an edger, a trimmer, a steaming shed, and a dry kiln.

The 576-log sample contained an excellent distribution of diameters and lengths (Fig. 2). Each log was numbered and sketched to show all visible characteristics on its surface and ends. Measurements included diameter and length and the size and relative location of all surface and end blemishes. Lumber yield was identified with the parent log and recorded green by thickness, width, length, and grade at the green chain. Grading was done in accordance with National Hardwood Lumber Associaiton rules for walnut. Of the 576 logs studied, 522 were categoried by three merchantable quality classes. Of the 54 remaining, 14 were discarded because of insufficient data; 40 were classified as cull.

Analysis and Results

The value of each log expressed as a quality index[2] was then computed on the basis of sawed lumber volume, thickness, and grade. With these values, it was then possible to group logs with approximately the same values. During this grouping process, two facts became obvious. First, the volume of walnut produced in 6- and 7-foot logs justifies lowering the length requirement to 6 feet for all grades, and second, because of the premium price paid for thick lumber, especially in the two top grades, the diameter requirements for top-grade logs should also be lowered. For example, comparison of logs on the basis of the percentage of high-grade lumber produced frequently showed 11- and 12-inch logs producing comparable percentages of high-grade lumber with 15- and 16-inch clear logs. Yet, when these same logs were compared by quality index, the larger logs were always appreciably more valuable. The obvious reason, of course, was that the sawyer sawed thicker lumber in the top grades from the larger logs than he sawed from the smaller ones. A comparison of two logs shown in Table 1 illustrates this important point.

The difference in total lumber yield for the two logs is 31 board feet. Putting it another way, the 15-inch log yielded about 40 per cent more lumber than the 12-inch log. This is exactly the amount of 10/4 and thicker lumber cut from the 15-inch

[2] References 2 and 5 on the development of quality indices at the end of paper.

Fig. 1.—Close-up of the Tomlinson Lumber Co. sawmill, Winchester, Ky.

[1] Contributed paper (received Feb. 1958) from the Tennessee Valley Authority, Division of Forestry Relations. Research aspects of the study are available from the TVA Division as Report No. 218–57.

The Author: W. W. King graduated from [illegible] State with a BS in forestry, and received his MF degree in forest utilization from Duke University. He was affiliated with Texas A&M College in various research capacities with the Forest Products Department of the Texas Forest Service before joining TVA three years ago.

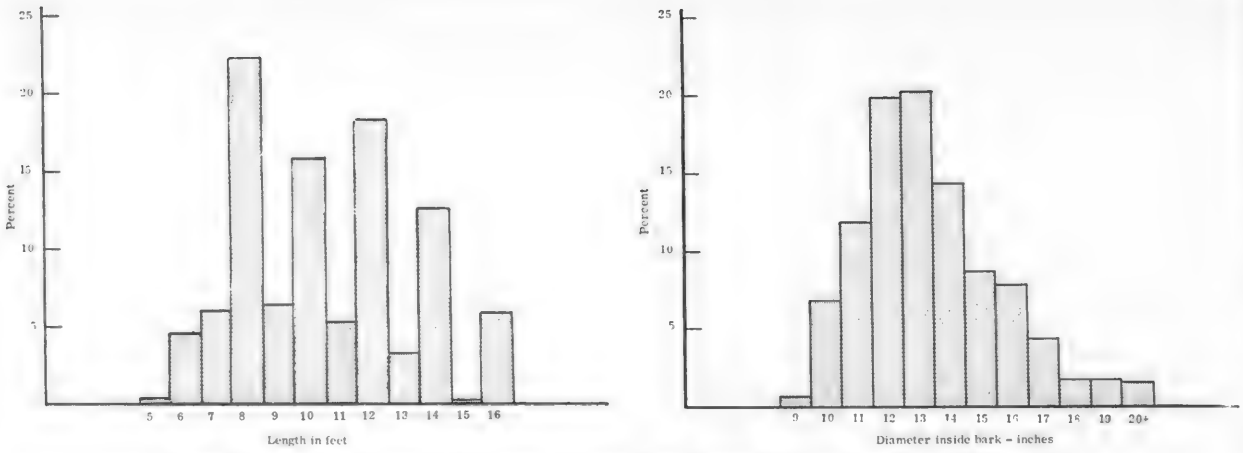

Fig. 2.—Length and diameter distribution of walnut logs. Seven 9-inch top logs included in sample.

Table 1.—COMPARISON OF TWO PRIME WALNUT LOGS SHOWING EFFECT OF LOG SIZE ON LUMBER YIELD BY GRADE, THICKNESS, AND VALUE

	Log 1	Log 2
DIB (inches)	12	15
Length (feet)	12	12
Yield (board feet)	76	107
Per cent FASIF and Better	79	78.5
Per cent 4/4, 5/4, 6/4 lbr.	55	34
Per cent 8/4 lbr.	45	26
Per cent 10/4, 12/4, 16/4 lbr.	0	40
Quality index	1.65	2.00
Lumber value per Mbf	$346.50	$420.00

log. And that accounts for the difference of $73.50 per thousand board feet in the values of the two logs.

Full consideration was given all measurable log factors for four groups of logs with similar lumber-grade yields. Only those indicative of log quality and having the closest relationship with the essential elements of lumber-grade yield were used. The resulting four log quality classes are identified as Prime, Select, Common, and Cull (Fig. 3). The log characteristics that yield these grades are tabulated in Table 2.

Table 2.—SPECIFICATIONS FOR WALNUT SAWLOG QUALITY CLASSES BASED ON N.H.L.A. RULES FOR GRADING WALNUT LUMBER

Quality factors	Prime[1]	Select[2]	Common[3]
Minimum diameter			
Butts	12″	12″	
Uppers	13″	13″	9″
Minimum length	6′	6′	6′
Minimum clear faces (out of four)	two clear and one 5/6 clear	one clear and two 2/3 clear	none clear and three 2/3 clear
Clear cuttings			
Length	4′ and up	3′ and up	2′ and up
Maximum number on face	2	3	unlimited
Maximum cull deduction[4]	25%	33⅓%	50%
End defects	See instructions in text		

Exceptions:
[1]Will admit 11″ butts and 12″ uppers with 3 clear faces and 1 face 5/6 clear, also 16″ butts and uppers with 1 clear face and 2 faces 5/6 clear.
[2]Will admit 11″ butts and 12″ uppers with 2 clear faces and 2 faces ⅔ clear, also 16″ butts and uppers with no clear faces and 3 faces ⅔ clear.
[3]Logs that do not meet specifications for Common quality are Cull.
[4]Logs whose combined scale deduction for sweep and cull exceeds the maximum allowable are dropped into the appropriate quality class.

A basic requirement of any log grading system is that it must be reasonably accurate for small groups of logs. Statistical tests of this system proved that as few as 29 Prime logs, 40 Select logs, and 28 Common logs would give results within plus or minus 5 per cent of average steam-treated lumber value in each quality class, with only one chance in 20 of failing.

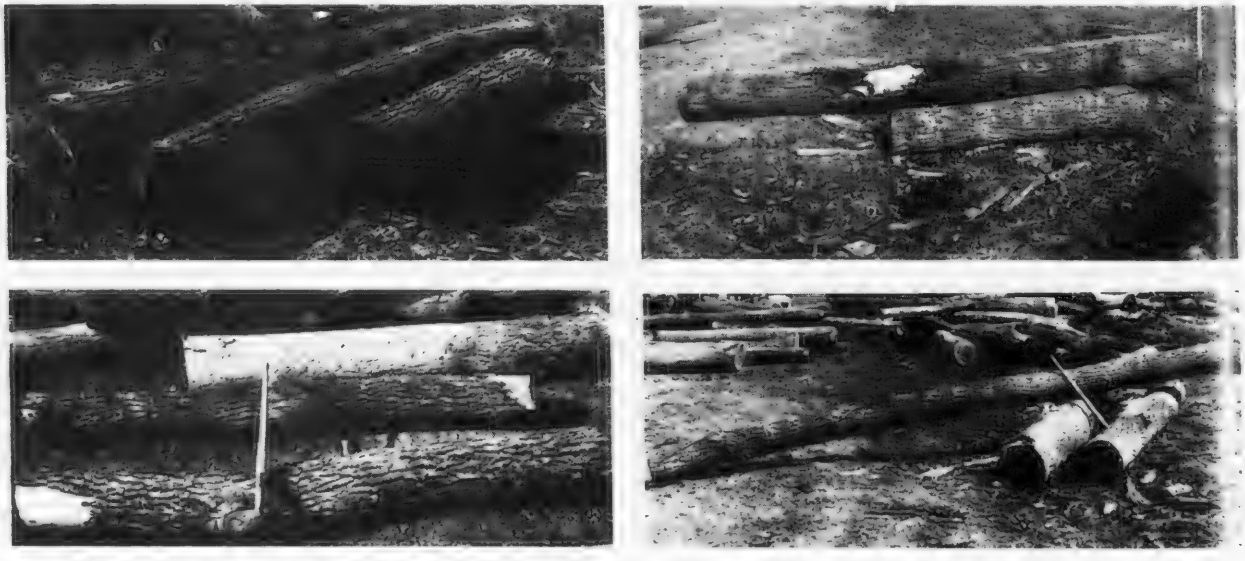

Fig. 3.—Typical examples of prime (upper left), select (upper right), common (lower left), and cull (lower right) walnut logs.

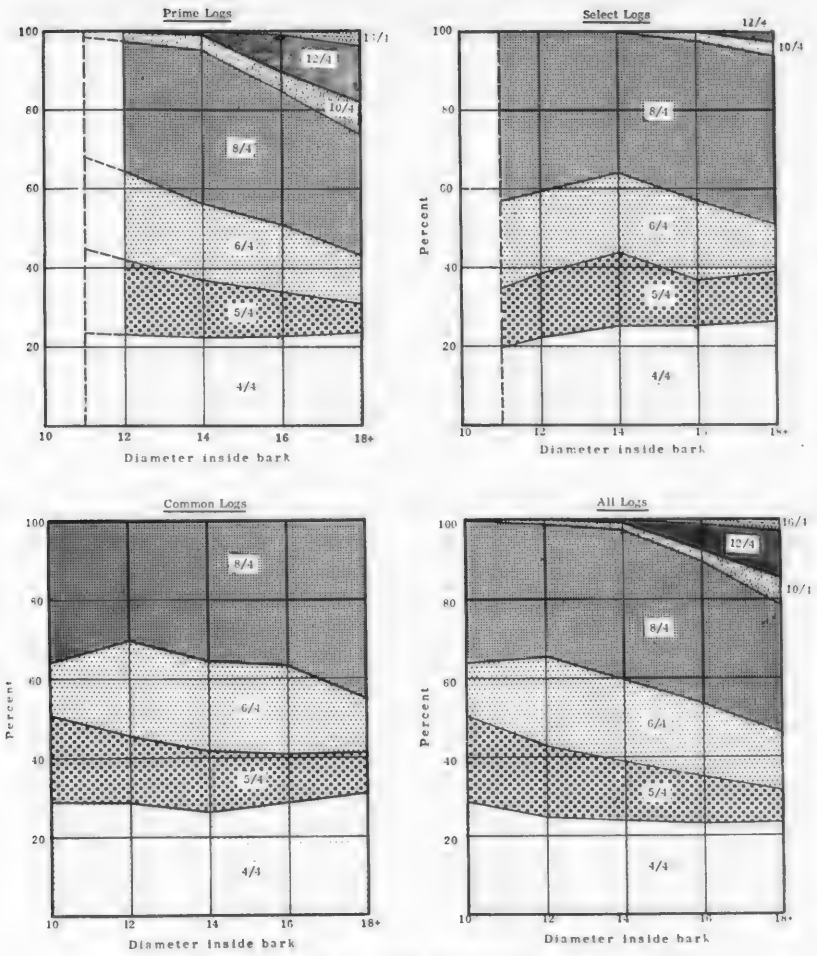

Fig. 4.—Relationship of lumber thickness and log diameter

Log and Lumber Relationships

Information on the four principal relationships involved in the conversion of walnut logs to lumber is presented as an aid to understand the mechanics of the log quality system. These relationships include 1) lumber thickness and log diameter, 2) lumber grade and log diameter, 3) lumber thickness and lumber grade, and 4) lumber grade yield and quality class.

Lumber Thickness and Log Diameter: In the walnut trade, prices not only increase with grade, but also with thickness. Prices are highest on thick lumber in the better grades.

Experience shows that, as log diameter increases, the possibility of cutting thicker lumber in the upper grades also increases. This places a tremendous burden on the sawyer. His failure to recognize the quality inherent in a given log can result in unrecoverable losses once a line is cut. Suppose, for example, a sawyer cuts three 4/4 FAS boards from a given log and then discovers he could have cut a 16/4 FASIF plank. The three 4/4 boards are worth $440 a thousand board feet, whereas the one 16/4 plank is worth $655 a thousand.[3] Assuming the lumber to be 8 inches wide and 12 feet long, the mistake would cost the company $7.20, plus additional sawing and handling costs.

Fig. 4 shows the relationship of lumber thickness and log diameters at the study mill. Notice that no lumber thicker than 8/4 was cut from Common logs. No stock thicker than 12/4 was cut from Select logs; only Prime logs 14 inches and larger yielded the 16/4 thickness.

Lumber Grades and Log Diameter: If all logs were free of the visible defects that cause lumber degrade, it would be a simple matter to establish log quality solely on the basis of diameter. There would possibly be a size difference between certain species because some species prune earlier than others. This would be reflected in the size of the knotty central core. But quality could be established simply on the basis of clear wood in the ring outside the central core. Because numerous other defects do cause lumber degrade, however, it becomes necessary to relate all visible defects in combination with log size to the requirements of the various lumber grades.

[3] Lumber values per thousand board feet based on steam treated lumber price quotations f.o.b. car, Winchester, Kentucky, May 16, 1956.

Table 3.—PERCENTAGE DISTRIBUTION OF LOG SAMPLE BY DIB CLASSES WITHIN QUALITY CLASSES

Diameter class	Prime	Select	Common	All
	Per cent			
10	--	--	100	100
12	35	28	37	100
14	46	36	18	100
16	60	27	13	100
18+	69	17	14	100

Extreme variation in frequency, kind, size, and distribution of defects is perhaps the chief reason for the range of diameters usually found within each quality class (Table 3). Therefore, the combination of diameter and other quality indicators is superior to ranking logs by diameter alone. This is shown graphically in Fig. 5. For illustrations, the yield of FAS lumber for all 14-inch logs is approximately 30 per cent. However, 14-inch Prime logs yield 40 per cent, Select logs about 25 per cent, and Common logs about 10 per cent. Thus a buying policy based on diameter alone subsidizes the producer of low-quality logs and provides no incentive to the producer of high-quality logs.

Since the percentages of high-grade lumber increase with diameter, it is easy to show that log value based on steam-treated lumber value also increases with diameter. For example, all 14-inch walnut logs studied had a mean value of approximately $306.60 per thousand board feet. But Prime 14-inch logs were worth $344.40 per thousand, Selects $289.80, and Common only $224.70. The value difference, therefore, between 14-inch Common and Prime logs is $119.70 per thousand board feet. Between Common and Select logs the difference is $65.10; between Select and Prime logs it is $54.60.

Lumber Thickness and Lumber Grade: The data show the substantial difference in the amount, grade, and thickness of lumber that can be sawed from logs of different quality. It is only reasonable to expect, therefore, that Prime logs should yield the greatest percentage of top grade, thick stock, while Common logs should yield the bulk of the thinner, lower grades of lumber.

Table 4 shows that 27.3 per cent of the lumber from Prime logs was in the two top grades and at least 8/4 thick. The percentage was 15.5 for Select logs and 3.3 for Common logs. The percentage of 10/4 and thicker stock was 10.4 for Prime, 1.2 for Select, and zero for Common logs. Finally, the combined yield of 6/4

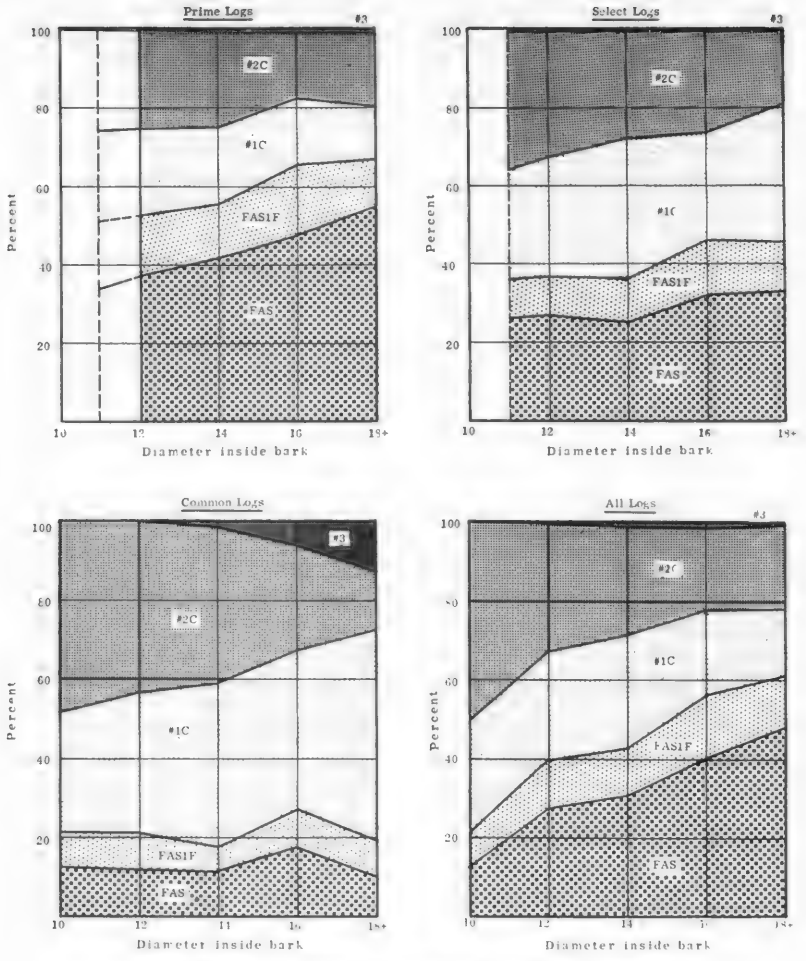

Fig. 5.—Relationship of lumber grade and log diameter.

Table 4.—PERCENTAGES OF LUMBER VOLUME BY THICKNESS AND LUMBER GRADE

Thickness	FAS	FAS1F	#1C	#2C	#3	All grades
			Prime Logs			
4/4	9.5	3.5	6.9	2.6	0.0	22.5
5/4	7.1	1.8	3.1	1.5	0.0	13.5
6/4	7.6	2.7	3.4	4.5	0.0	18.2
8/4	12.1	4.8	4.6	12.6	0.3	34.4
10/4	3.1	0.7	0.1	0.1	0.1	4.1
12/4	4.1	1.5	0.3	0.2	0.0	6.1
16/4	1.0	0.0	0.2	0.0	0.0	1.2
Total	44.5	15.0	18.6	21.5	0.4	100.0
			Select Logs			
4/4	6.9	3.8	10.7	3.5	0.0	24.9
5/4	5.0	1.2	6.1	2.0	0.0	14.3
6/4	5.1	2.1	6.6	5.2	0.0	19.0
8/4	10.0	4.3	9.4	16.0	0.6	40.3
10/4	0.3	0.2	0.0	0.0	0.0	0.5
12/4	0.3	0.4	0.3	0.0	0.0	1.0
16/4	0.0	0.0	0.0	0.0	0.0	0.0
Total	27.6	12.0	33.1	26.7	0.6	100.0
			Common Logs			
4/4	4.7	3.3	14.1	5.8	0.1	28.0
5/4	2.8	2.2	8.2	3.4	0.0	16.6
6/4	2.5	1.5	9.0	7.3	0.4	20.7
8/4	1.9	1.4	6.7	23.5	1.2	34.7
10/4	0.0	0.0	0.0	0.0	0.0	0.0
12/4	0.0	0.0	0.0	0.0	0.0	0.0
16/4	0.0	0.0	0.0	0.0	0.0	0.0
Total	11.9	8.4	38.0	40.0	1.7	100.0
			All Quality Classes			
4/4	7.8	3.5	9.4	3.5	0.0	24.2
5/4	5.6	1.8	5.0	2.0	0.0	14.4
6/4	5.8	2.3	5.4	5.3	0.1	18.9
8/4	9.4	4.0	6.3	15.8	0.5	36.0
10/4	1.7	0.4	0.1	0.1	0.1	2.4
12/4	2.3	0.9	0.2	0.1	0.0	3.5
16/4	0.5	0.0	0.1	0.0	0.0	0.6
Total	33.1	12.9	26.5	26.8	0.7	100.0

and thinner No. 1 Common lumber from Prime logs was 13.4 per cent; Select logs yielded 23.4 per cent; Common logs 31.3 per cent.

Quality Class and Lumber Grade: Probably the most compelling reason for grading logs is the basis it provides for predicting profit. This means that buyer and seller alike should understand the relative values of the raw woods product. And the only way this potential value can be measured is to base log quality on the market value of the lumber produced. Therefore, if a log grading system is worth anything at all, it must indicate or predict lumber yield by grade. The lumber grade yields of the log quality classes developed at this one mill are given in Table 5. Of course, variations should be expected from mill to mill because of sawyer ability, but yields between quality classes should remain approximately relative.

These figures lead to several conclusions concerning log quality and lumber grade yield:

1. Prime logs in this study yielded about 60 per cent FASIF and Better lumber and about 80 per cent No. 1 Common and Better.
2. Select logs yielded about 40 per cent FASIF and Better lumber and about 70 per cent No. 1 Common and Better.
3. Common logs yielded about 20 per cent FASIF and Better lumber and about 60 per cent No. 1 Common and Better.
4. The decrease in FAS lumber from Select logs, as compared with Prime logs, is about the same as the increase in No. 1 Common lumber.
5. The decrease in FAS lumber from Common logs, as compared with Select logs, is about the same as the increase in No. 2 Common lumber.

Table 5.—PERCENTAGES OF LUMBER VOLUME BY LUMBER GRADE AND QUALITY CLASS

Quality class	FAS	FAS1F	#1C	#2C	#3
Prime	44.5	15.0	18.6	21.5	1.4
Select	27.6	12.0	33.1	26.7	.6
Common	11.9	8.4	38.0	40.0	1.7
All classes	33.1	12.9	26.5	26.8	.7

Table 6.—NET LOG VALUES BY DIAMETER CLASSES WITHIN QUALITY CLASSES PER 1000 BOARD FEET GREEN
Seven 9-inch top logs included in sample.

Quality class	Diameter class	Gross log[1] value	Quality index	Less costs plus profit	Net log value
Prime	11, 12, 13"	$325	1.55	$185	$140
	14, 15, 16"	365	1.74	170	195
	17" and up	405	1.93	165	240
Select	11, 12, 13"	275	1.31	185	90
	14 and 15"	295	1.40	170	125
	16" and up	315	1.50	165	150
Common	9 to 13"	210	1.00	190	20
	14" and up	240	1.14	170	70

[1]Log value based on market quotation of $210 per Mbf No. 1 Common. When price of 4/4 No. 1 Common changes, multiply current price by quality index value shown to obtain new current gross log value. All log values FOB mill.

Applying the Rules[4]

To be useful, a log grading system must be understandable and easy to apply. The following discussion covers definitions nad procedures for applying the rules.

Definitions: Log face—one of four equal sides of a visually squared log. Clear face—a log face entirely free of defect. Clear cutting—full width portion of log face between defects or between the end of the log and a defect. Defect (end or surface)—a visible indication of an internal log condition that will lower the value of lumber. Scale deduction—an estimated board-foot volume deducted from gross log scale because of defect. The most common defects that require scale deductions are sweep and crook, splinter pull, presence of metal, fire scar, and rot (usually confined to the sapwood of walnut).

Defects and Clear Cuttings: Clear cuttings allow no knots except pin knots, and no metal or any indication of its presence.

Fire scar, seams, and frost cracks that involve less than one-fifth of the diameter of the log are not considered defects. Stain is not a defect.

Sound end defect, the most typical being twin or multiple heart, is not considered a defect if confined to the heart zone (one-fifth log diameter measured from pith). When twin heart lies wholly or partially outside the heart zone, however, it prevents clear cuttings from the log face affected. Unsound end defects (ring shake, heavy dote, or decay) extending more than half the distance from heart zone to log surface prevent clear cuttings on the face affected.

End defects like bird peck and wormholes (usually associated with fire scar, frost cracks, rot, or injury) are not considered defects unless they lie outside the heart zone. When such defects (at either end of log) affect one-half the radial distance from heart zone to bark in two adjoining faces, otherwise Prime and Select logs must be degraded one quality class.

[4] See Table 2.

Sweep, Crook, and Cull Deduction: The following rules[5] are recommended for making scale deductions in black walnut:

Sweep—For 16-foot logs, measure actual sweep in inches, subtract 2, and divide by log diameter. This is the per cent of total log volume to deduct. For 8-foot logs, subtract 1 from inches of sweep and divide by diameter. For other log lengths, subtract proportionate amounts—¾ for 6-foot logs, 1¼ for 10-foot logs, 1½ for 12-foot logs, and 1¾ for 14-foot logs.

Cull—Cull deductions may be made by using the squaring system as follows:

$$\frac{(\text{width}'' + 1'') \times (\text{height}'' + 1'') \times \text{length}'}{15} = \text{cull deduction in bd. ft.}$$

This figure must then be multiplied by the following factors, depending on whether logs are scaled by the Doyle or International log rule.

Log diameters	Multiplying factors: Int. ¼" Rule	Doyle Rule
8"–14"	1.2	
15"–19"	1.1	
8"–11"		0.6
12"–13"		0.8
14"–20"		0.9

Deduction for cull does not raise the quality of a log, even though in some cases it may appear that removing the cull will raise the average grade of usable lumber produced. The culled portion may or may not affect clear cuttings. If it does, it is a defect.

Determining Quality Classes: With the above information, the rules can now be put to work. The following procedure is suggested. The procedures becomes routine with practice.

Step 1. Determine whether log is a butt or upper.

Step 2. Measure diameter of log at small end, inside the bark. Examine both ends for defects that influence quality.

[5] Lockard, C. R. Manual for Hardwood Log Grading in the Northeast. Northeastern Forest Experiment Station, Forest Service, USDA, Upper Darby, Pa., September, 1945, Revised April, 1956.

Step 3. Compute sweep and cull deductions, if any, and determine net scale of log.

Step 4. Visually square log into four equal faces in such a way as to obtain the greatest number of clear faces. Include as many defects as possible in a single face. Always confine the influence of a single defect (such as a large knot) to a single face.

Step 5. Determine the number of clear faces, and partially clear faces[6] on the basis of clear cutting requirements.

Step 6. Determine quality of log on the basis of the combined effect of size, position (butt or upper), clear faces, clear cuttings, and scale deductions.

Development of Log Price Schedule by Grade, Diameter and Length

Additional application of the results of this study was made to assist walnut lumber producers determine the relative value of logs by size and quality. For those who are interested in such a procedure, the mechanics involved in developing a log pricing structure are given below.

Step 1. Determine the cost of producing walnut lumber by various log sizes. This can be done by one-inch classes; but for this purpose log sizes can be grouped to simplify the procedure. Include all costs, both manufacturing and non-manufacturing, and add a reasonable profit, say 15 per cent.

On the following page we have assigned relative milling costs based on selected groups of log diameters and quality.

[6] For 5/6 clear faces, multiply length of log in feet by 10; result is the required clear face length in inches. For 2/3 clear face, multiply length of log in feet by 8. For ½ clear face, multiply length of log in feet by 6. Example: A 5/6 clear face is required of an 11-foot log in two cuttings, the minimum one being 4 feet. Multiply $11 \times 10 = 110$ inches. If one cutting must be 4 feet (48 inches), the larger cutting must be at least 62 inches (110 − 48 = 62).

Table 7.—GREEN LUMBER YIELDS BY DIAMETERS AND LENGTHS WITHIN QUALITY CLASSES

Quality class	Diameter class	6–7′	8–9′	10–11′	12–13″	14–16′
				Board Feet		
Prime	11, 12, 13	30	45	60	75	90
	14, 15, 16	65	80	100	120	145
	17 and up	95	115	145	175	200
Select	11, 12, 13	30	45	60	75	90
	14, 15	55	75	95	115	135
	16 and up	70	100	130	155	190
Common	9 to 13	30	40	50	60	80
	14 and up	65	90	115	140	170

Table 8.—MAXIMUM LOG PRICE BASED ON ARBITRARY PRODUCTION EXPERIENCE AND PROPOSED WALNUT SAWLOG QUALITY CLASSES

Quality class	Diameter class	6–7′	8–9′	10–11′	12–13′	14–16′
Prime	11, 12, 13″	$ 70	$105	$140	$175	$210
	14, 15, 16″[1]	125	150	190	230	275
	17″ and up	155	190	240	290	340
Select	11, 12, 13″	45	65	90	110	135
	14 and 15″	70	95	120	140	170
	16″ and up	90	130	150	180	220
Common	9 to 13″	15	20	25	30	40
	14″ and up	40	55	70	85	105

[1] Prime logs above 17 inches are veneer quality logs and price is generally determined by the market price of walnut veneer logs. However, it is possible for logs this size to fall in the Prime sawlog class. Prices are FOB mill.

Log diameters		Milling costs per M bd. ft.[7]
11, 12, 13	Prime and Select	$50
14, 15, 16		40
17 and up)		35
9-13	Common	55
14 and up)		37

To each of the above milling costs[8] must be added labor costs for sorting, stacking, grading, loading, steaming, drying, and so forth; and non-manufacturing costs such as salaries for management, office, sale, and overhead. Assume for this example, labor costs are $75 and non-manufacturing costs are $35 per M board feet, green lumber tally.

Step 2. This step involves data derived from the present study. The basic figures are obtained from the weighted average values of logs of specific diameters by quality classes. Table 6 shows the resulting net log values by diameter and quality class.

Step 3. Set up a table of lumber yields, based on local experience, for the various log lengths and diameters in the quality classes (Table 7). It takes 50 nine-inch logs eight feet long to produce 1000 board feet of lumber, whereas it takes only 20 nine-inch logs 16 feet long to produce the same amount. It should be pointed out that, while it does require somewhat more time to saw through the 16-foot log, loading and turning time on the additional logs required are the chief reasons for increased sawing costs on short logs.

Step 4. The final step is to apply the volumes shown in Table 7 to the net log values in Table 6. This is done as follows: The net log values in Table 6 are based on the average log length in each quality class. The average length of all sample logs was between 10 and 11 feet. The volume for this length is therefore assigned a factor of 100. Volumes for longer and shorter logs are then converted to percentages of this volume. For example, in the Prime quality class, the volume of the 11-, 12-, and 13-inch diameter logs, 10 to 11 feet long is 60 board feet. The 30 feet in the 6 to 7-foot class is 50 per cent of 60, the 45 feet in the 8- to 9-foot class is 75 per cent, and so forth. Application of these percentages to the net log values in Table 6 gives the maximum log prices that can be paid by quality, diameter, and length. Table 8 gives these prices rounded off to the nearest $5.00.

[7] These costs do not necessarily reflect costs of cooperating mill.

[8] Should include losses from shrinkage, degrade, metal in logs, and other losses.

Summary

Although American black walnut is our highest priced native wood, the walnut industry has had access to very little information on the fundamental relationships between sawlog quality and standard walnut lumber yield. This article, based on a recent study, attempts to develop a sound basis for evaluating walnut log quality.

The specifications developed are practical and accurate for small groups of logs, and are easy to learn and easy to apply. They should help the walnut processor realize a greater profit.

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Chemical Conversion of Wood Residues Part I: Separation and Utilization of Hardwood Hemicelluloses[1]

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Hardwood residues are increasing along 2 lines: hardwood lumber and pulp operations, with attendant residues, are increasing greatly, and much otherwise unproductive land is being covered with widely mixed, difficult-to-use hardwoods. Profitable chemical utilization depends on full use of the 3 major components—hemicellulose, cellulose, and lignin. This paper, first of a long-range series, deals with hemicellulose processing that leaves the other components in optimum condition.

THIS PAPER DEALS WITH an important aspect of chemical utilization research currently in progress at the Forest Products Laboratory—research directed at utilization of residues that have no structural or fiber values. The main emphasis is on hardwoods, because our present forest economy makes it necessary to process increasing quantities of hardwoods for both lumber and pulp, with the result that greater quantities of hardwood residues are on hand. Added to this situation is the fact that the major part of the Nation's unproductive forest land is covered with little-used mixed hardwoods, which cannot at present be economically removed to allow reforestation with more useful species. A factor complicating the utilization of these residues is the large variety of species involved, which results in a non-uniform raw material for any

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utilization process. This variety makes physical utilization rather improbable, but such non-uniform material could conceivably be easily processed by chemical means. Thus, an economical chemical process for hardwood utilization could provide the impetus for important progress in a forest utilization program.

Detailed reviews of the numerous attempts at utilization by saccharification have been presented recently (3, 5),[3] and the economic reasons for commercial failure have been analyzed. The important result of this analysis can be summarized in the main as follows:

Most previous attempts have failed to take full account of the fact that wood is a complex substance, composed of three major components—hemicellulose, cellulose, and lignin—and that any completely successful process must fully utilize each of these components. To obtain optimum yields from each of the fractions requires that they be separated and processed independently, because the conditions of optimum yield for one fraction do not coincide with those for the others. Separation must be as clean and gentle as possible, and each fraction must subsequently be processed into products especially well suited for production from that particular component. Discussed here are some of the aspects of the problems involved in separating and utilizing the hemicellulose fraction of hardwoods. The corresponding material from softwoods presents an entirely different utilization problem that is not to be considered here.

Methods of Removing Hemicellulose

The suitability of a particular method of separating the hemicellulose from the other portions of the wood can be critically judged only in the light of an over-all process that yields known end products. In general, however, the process should make possible a high degree of separation at a low cost and rapid rate. The residue should be chemically unchanged and free of undesirable impurities. A final point: it would be highly desirable that the separation process be tailored to the subsequent processing of the hemicellulose or the sugars derived from it.

Hydrotropic Pulping Agents: An examination of the known means of removing hemicellulose from wood reveals two promising commercial techniques. One of these is removal of the hemicellulose and lignin by means of hydrotropic pulping agents, such as sodium xylenesulfonate or sodium benzoate. This method of lignin removal has been suggested (4, 6, 7) for some time as an economical pulping method, and on the surface appears to have considerable merit. However, it has not gained general use as a pulping method. This may be because of undesirable qualities in the pulp fiber, incomplete lignin removal, or some other disadvantage from a pulping viewpoint. From the viewpoint of chemical utilization, it has several assets that warrant investigation to evaluate its potentiality for this application.

The possibility of hydrotropic removal of the lignin and hemicellulose is made attractive by the fact that lignin of uniform quality can apparently be removed with only a small amount of degradation in rather high yield. Should this lignin become a valuable fraction, the value of this method of separation would be enhanced because it removes it from the cellulose fraction without subjecting it to unduly high temperature or chemical attack. This is the main justification at the present time for beginning a research project concerned with hydrotropic separation.

Prehydrolysis: The other separation technique considered of interest is the familiar method of prehydrolysis, or mild hydrolytic cleavage and solubilizing of the hemicellulose with heat and dilute sulfuric acid. This method is inexpensive, requires simple equipment, follows known techniques, and fits in well with subsequent processing of the derived pentose sugars.

Research was begun on the removal of hemicellulose by hydrolysis with the conviction that the work would be of interest not only from the chemical utilization standpoint, but also to pulp and hardboard manufacturers. For this reason, the study was made as broad as possible commensurate

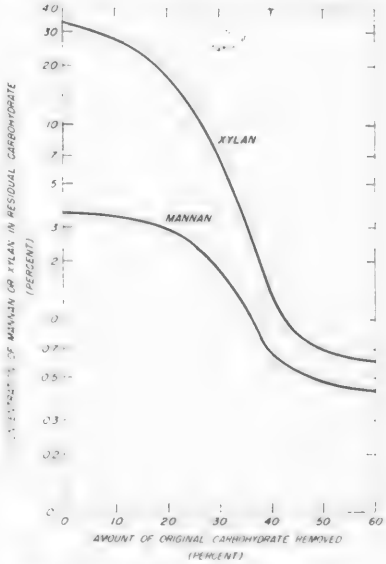

Fig. 1.—Variation of residual carbohydrate composition during the hydrolysis of southern red oak. Catalyst, 0.0 to 1.6 per cent aqueous solution of sulfuric acid; temperature, 170° to 190° C.; liquid-to-solid ratio, 8:1.

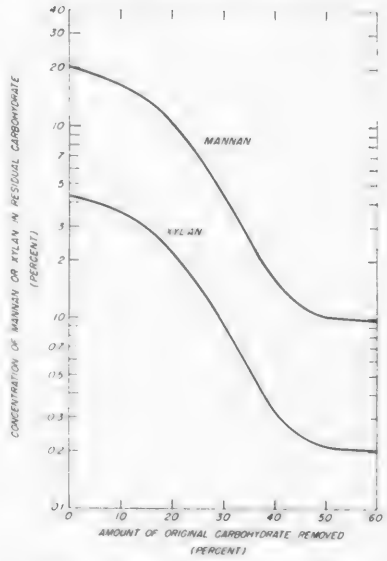

Fig. 2.—Variation of residual carbohydrate composition during the hydrolysis of Douglas-fir. Catalyst, 0.0 to 1.6 per cent aqueous solution of sulfuric acid; temperature 170° to 190° C.; liquid-to-solid ratio, 8:1.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

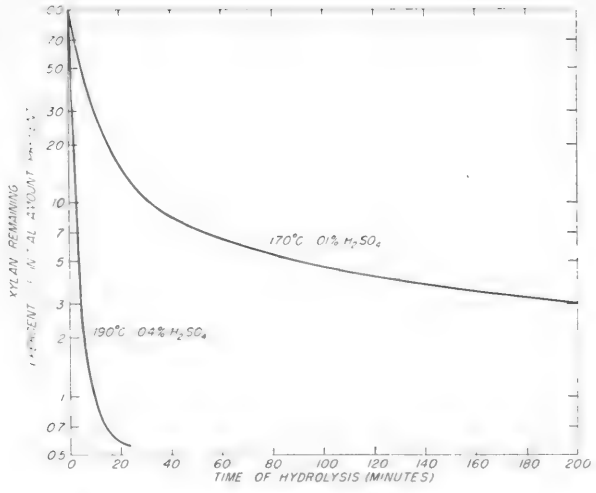

Fig. 3.—Relative hydrolysis rates for southern red oak.

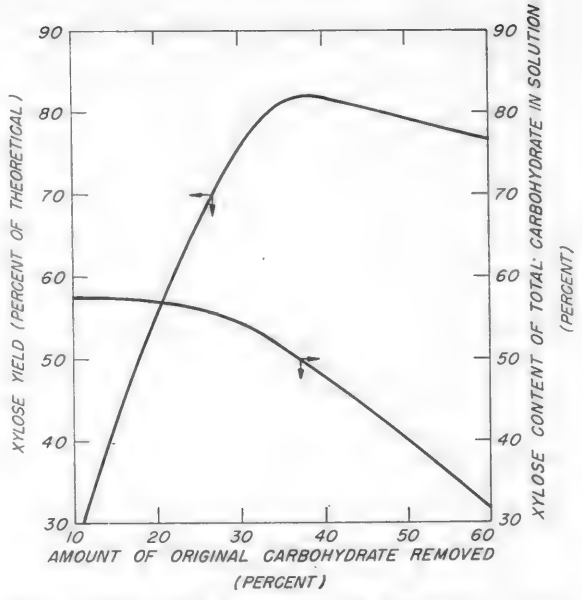
XYLOSE YIELD (PERCENT OF THEORETICAL)
XYLOSE CONTENT OF TOTAL CARBOHYDRATE IN SOLUTION (PERCENT)
AMOUNT OF ORIGINAL CARBOHYDRATE REMOVED (PERCENT)

Fig. 4.—Xylose yields as a function of carbohydrate removal in hydrolysis of southern red oak. Catalyst, 0.1 per cent aqueous solution of sulfuric acid; temperature, 170° C.; liquid-to-solid ratio, 8:1.

with the amount of analytical work involved. Material was reacted in small glass ampules, and full advantage was taken of quantitative chromatographic techniques developed during the past few years (8). The quality and yields of the insoluble fraction were determined at various times, temperatures, and acid concentration levels. Analyses were made of the individual carbohydrates, glucose, mannose, and xylose, and of lignin. The resulting information was processed so as to reveal the underlying fundamental principles involved in the removal of the hemicellulose, with the hope that proper interpretation would lead to general applicability.

The nature of the work, of fundamental importance, is such that considerable time will be required to complete it. Briefly, the significant results are:

Regardless of the conditions of prehydrolysis chosen for removing the hemicellulose, the residual carbohydrate has a definite fixed composition dependent only upon the amount of the original carbohydrate solubilized. This is illustrated in Figs. 1 and 2, which show the concentration of mannan and xylan in the residue as a function of carbohydrate removal. The difference in removal of hemicellulose from softwoods is illustrated by Douglas-fir, shown in Fig. 2. Here the mannan and xylan are removed in directly proportionate amounts, so that about five times as much mannan as xylan is always present in the residue. On the other hand, in the particular oak sample illustrated in Fig. 1, the xylan and mannan drop to about the same concentration level, despite the fact that 10 times as much xylan as mannan was present in the original wood.

The second point of significance concerns the rate of removal, which can be made very rapid by increasing temperature and acid concentration. The magnitude of the effect is shown in Fig. 3. The variation is roughly what might be expected: doubling the acid concentration doubles the rate, and a 10° C. rise in hydrolysis temperature likewise doubles it.

The important processing criterion derived from the above results in that variation in processing conditions affects principally the rate at which things happen, and results in only minor variations in compositions and yields. The yield of pentose sugar from southern red oak is shown in Fig. 4 for a temperature of 170° C. and an acid concentration of 0.1 per cent. Yield would be approximately 5 per cent lower at 190° C. and 0.4 per cent acid, because of the increased rate of sugar decomposition at these conditions.

Utilizing the Hemicellulose Fraction

Considering now the utilization of the fraction resulting from the removal of the hemicellulose from the wood, the ideal way of using this material puts the following restrictions on the processing method and the desired product:

1. The product should have a large, expanding market and be as good as or better than existing commodities on the market which it might replace. It should be unique, obtainable from no source other than wood hemicellulose.

2. The process should, of course, be of low cost, require low capital investment, and be readily integrated with existing wood processing industries. It should be able to use the hydrolyzate fraction directly without further refining, and present a negligible waste disposal problem.

Industrial products that have been suggested and tested are cattle feed molasses and yeast made of sugars from the hemicellulose hardwood fraction. The molasses that can be produced is a product comparable to blackstrap molasses from the cane sugar industry, and in general commands the same price at the point of consumption. The cost of production and its value as a feed are covered in part by Forest Products Laboratory reports (1, 5). It has a disadvantage when compared to blackstrap in that the pentose sugar can be utilized only by ruminants, and its use therefore is restricted to cattle. This is a very minor disadvantage, compensated for to some extent by the fact that acetic acid always present in this molasses is utilized by ruminants. The production of Torula yeast from wood-sugar molasses, including pentose sugars, is the subject of another report (2). Again although xylose has no major disadvantages in comparison with glucose it has no advantages and must compete with blackstrap molasses on a direct basis as a raw material.

These ways of utilizing the hemicellulose, although fulfilling some of the

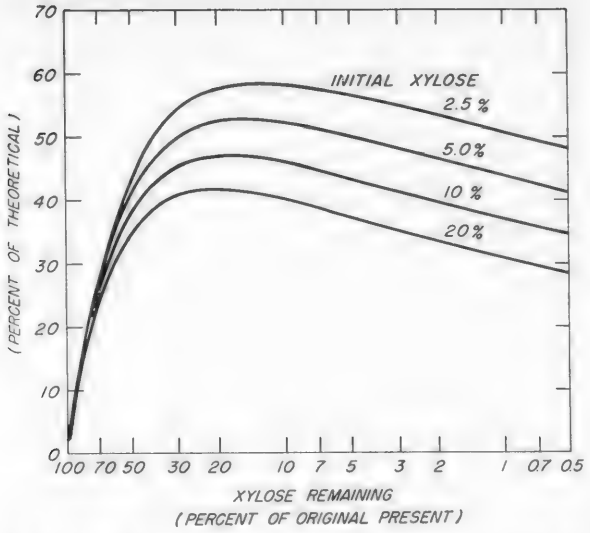

Fig. 5.—Effect of initial xylose concentration on furfural yields obtained from hardwood pentosans by hydrolysis with a 0.5 to 4 per cent aqueous solution sulfuric acid at 200° C.

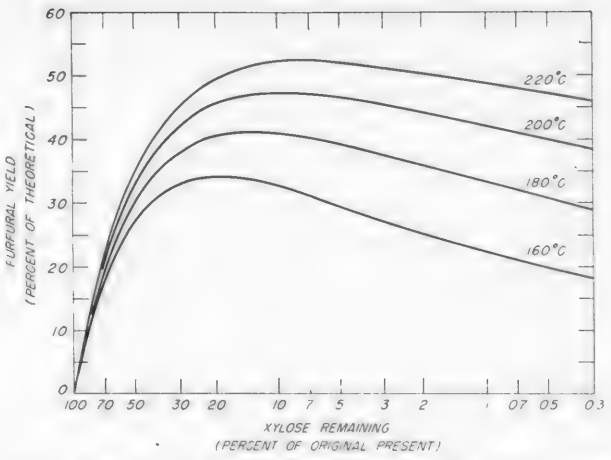

Fig. 6.—Effect of temperature of reaction on furfural yields obtained from hardwood pentosans by hydrolysis with a 0.5 to 4 per cent aqueous solution of sulfuric acid. Initial xylose concentration, 10 per cent.

requirements of a good utilization procedure as previously outlined, do not take any advantage of the fact that most of the hemicellulose fraction from hardwood consists of pentose sugar. An advantage can be secured in two ways: it can either be processed into products that are at present obtained from glucose but can be obtained more cheaply or in better yield from xylose, or into products that cannot be produced from glucose. Much work needs to be done in this field of market research to give direction to future research, but at present there is at least one commercial chemical that can be made only from xylose. This chemical is furfural, and its production from hardwood hemicellulose would take full advantage of the unique character of this fraction.

The largest single use for furfural is as an intermediate for the manufacture of nylon, and because of the great expansion occurring in this industry, considerable interest in increasing the production of furfural has been indicated over the past few years. The market situation is such that, at the current price level, at least twice the Nation's current annual production of furfural could be consumed but for the fact that the present raw material, corncobs, cannot be collected in greater quantities at a competitive price for furfural. A survey of the raw materials that might be used leads to the conclusion that increased domestic production of furfural can only come from hardwoods. This fact leads to consideration of the possibility of producing furfural in an integrated utilization process.

As already pointed out, a successful chemical utilization process for hardwoods almost surely must separate the wood components for individual processing, which means that the xylan of the hemicellulose would be present as xylose in solution. Subsequent processing, then, would yield furfural in acidic aqueous solution by a process much different than that used in present commercial practice. Data in the range of interest desired were not available, so research on the kinetics of the production of furfural from acidified xylose solutions was begun several years ago. This research has now been terminated (8), but Figs. 5 and 6, based on some of the early data collected, give an indication of the important results of the work. These diagrams show the very pronounced effect on maximum yield that is due to variations in both initial sugar concentration and reaction temperature. Increase of the maximum yield occurs with increasing temperature and decreasing initial xylose concentration.

Of course, these gains do not continue indefinitely. But the range of temperature investigated has gone as high as 300° C. and the dilution has been carried as low as 0.5 per cent of the initial xylose, and at these conditions, which are very favorable for a high maximum yield, over 75 per cent of the theoretical yield has been attained. These yields are for a single-pass operation, with all the products of the reaction remaining in contact with the reactants until the reaction is halted. The high yields quoted are very impressive in view of the fact that the present commercial process gives yields of approximately 50 per cent. The principal effect of additional catalytic sulfuric acid is to hasten the rate of the reaction; it has no effect on maximum yield. The processing time required to reach maximum yield at 300° C. and 0.5 per cent sulfuric acid is approximately 1.2 seconds. Not shown in Figs. 5 and 6, but included in the research, were the effects of glucose in the solution on maximum yield. Its effect was appreciable at lower temperatures, resulting in a large decrease in yield, but at temperatures above 260° C. the effect became of minor consequence.

This information concerning the kinetics and yields of furfural production, coupled with the data on prehydrolysis outlined earlier, permits one to make fairly valid estimates of furfural yields that could be expected from hardwoods, and the processing procedure and conditions that should be used from these, production costs can be estimated. Furfural yields of 7.5 to 8.5 per cent, based on the weight of dry wood substance charged, can be expected from hardwoods containing 18 to 22 per cent of pentosan, and the cost of production at these yield levels is approximately the same as the current market price. In this estimate it is assumed that a share of the raw material cost proportionate to the hemicellulose content must be included in the cost of the furfural.

When the production of furfural is contemplated as the only product from the wood, this is not too attractive a picture. However, when the fact is considered that the furfural precursor, the pentosans, constitutes only 20 per cent of the raw material charged, the prospect of deriving profit from an integrated process looks very good. In other words, this information makes it almost certain that furfural production will have a prominent place in the utilization of hardwood residues, and further work

on the technical aspects of its production is therefore considered well worthwhile. Information such work can yield will eventually fit into the broad pattern of the complete scheme.

Future Work

A logical next step is a study of the technical problems involved in a small pilot-size reactor. The principal purpose of this work will be to appraise the fouling problem associated with the reaction. This is recognized as a most important technical problem. Information gained should find immediate application for evaluating the possibility of processing pentose solutions that are byproducts of prehydrolysis sulfate pulping and the hardboard industry. Present estimates indicate that a prehydrolysis sulfate pulp mill producing 200 tons of pulp per day would provide sufficient pentose in solution to warrant the installation of a furfural processing unit. This paper has considered only the use of hardwood hemicellulose. Concurrently, research is in progress on several aspects of utilizing the cellulose fraction. Research is also warranted on the utilization of the lignin fraction. The current outlook is that proper utilization of the carbohydrate fraction will lead to economic processing without the necessity of deriving profit from the lignin. Such a process, if developed, should stimulate sufficient interest to encourage wood processors to undertake chemical utilization, and simultaneously lead to expansion of research in the field, eventually establishing wood as a huge source of raw material for the chemical industry.

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Dimensional Stabilization of Wood
Part V. Phthaloylation[1,2]

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Phthaloylation imparts to wood the highest degree of dimensional stability yet observed, but because of the partially temporary character of the stability it imparts, phthaloylated wood could only be used to advantage as a dimensionally stable product in cases where the wood is subjected to normal changes in atmospheric humidity but not to soaking.

THE REACTION OF ACID CHLORIDES of dibasic acids with cellulose in the presence of pyridine yields insoluble and infusible derivatives. This is doubtlessly due to cross linking of the type usually obtained with polyhydroxy compounds and polybasic acids.

Frank and Caro[4] prepared cellulose oxalic esters by the reaction of acid chlorides of half esters of oxalic acid with cellulose in the presence of pyridine at elevated temperatures.

With chloroacetic anhydride used as an impelling agent, the acid form of half esters of succinic and phthalic acids were made to react with cellulose to yield cellulose succinates and phythalates (2).

Malm and Fordyce (7) have prepared cellulose half esters of dibasic acids with the second carboxyl group in the acid form. This was done by the reaction of the dibasic anhydride with cellulose in the presence of tertiary organic bases. Thus, cellulose acid phthalate was prepared from cellulose and phythalic anhydride, with pyridine used as the catalyst.

Products formed in this manner and which contain more than 25 per cent phthaloyl groups, are comparatively moisture resistant, but are readily converted into water-soluble salts by dilute alkali solutions. With heavier metals, these cellulose derivatives give salts that are insoluble in water.

Hiatt and Emerson (5) have patented a procedure for the preparation of cellulose mixed esters wherein a dicarboxylic acid anhydride with a melting point below 180° C. (including phthalic anhydride) is heated with a cellulose ether or cellulose ester (including cellulose acetate) with free and esterifiable hydroxyls, to a temperature between the melting point of the anhydride and 180° C. for a period of one to ten hours, depending upon the temperature.

A study of the mechanism of the reaction between phthalic anhydride and polyhydric alcohols was made by Brasseur and Champetier (1). They showed that linear polymers are first formed in a very rapid reaction, followed by a slower, crosslinking reaction through the remaining secondary hydroxyls. The kinetics were also studied by Shkol'man and Zeidle (10) who obtained similar results.

Nikitin and Corchemkin (8) have studied the effect of different pretreatments of cellulose upon the rates and degrees of its esterification with phthalic anhydride. They also showed that the acidic cellulose phthalate were not stable at 100 to 110° C., but that their copper salts were stable a

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[3] The paper was prepared while Dr. Arseneau was a graduate student at Laval University.

[4] Numbers in parentheses refer to Literature Cited.

Table 1.—EFFECTS OF SEVERAL VARIABLES ON ANTISHRINK EFFICIENCY AND REDUCTION IN WATER ABSORPTIVITY OF PHTHALOYLATED BLACK SPRUCE WHEN DIMETHYL PHTHALATE IS USED AS SOLVENT

Treating time, hours	Concentration of solution, g. Anhydride/ 100 ml. Solv.	Reaction temp., °C.	Weight increase, %	Anti-shrink efficiency, %	Reduction in water absorptivity, %
	100	Reflux	6.8	68.1	49.2
	100	Reflux	9.6	73.0	52.2
	100	Reflux	14.0	84.4	63.0
	100	Reflux	24.6	85.8	62.5
	100	Reflux	29.7	80.9	50.1
	100	Reflux	31.0	81.8	61.2
	10	Reflux	81.2	82.8	65.8
	20	Reflux	42.4	89.1	78.9
	27	Reflux	49.7	85.1	74.3
	30	Reflux	86.7	82.8	71.6
	40	Reflux	61.2	82.3	59.0
	100	25	2.0	30.5	11.3
	100	40	2.0	24.1	17.4
	100	59	11.7	58.9	38.1
	100	80	23.0	79.8	64.6
24	100	107	23.2	73.9	41.5

Table 2.—EFFECTS OF TREATING TIME AND REACTION TEMPERATURE UPON ANTI-SHRINK EFFICIENCY AND WEIGHT INCREASE OF BALSAM FIR PHTHALOYLATED WITH PHTHALIC ANHYDRIDE WHEN DIMETHYLFORMAMIDE IS USED AS SOLVENT

Reaction temp. °C.	Treating time Hours	Antishrink efficiency		Weight increase	
		First soak %	Second soak %	Before soak %	After soak %
80	1¾	92.4	76.6	50.4	29.9
	4	94.4	77.5	55.8	38.0
	7¾	100.0	83.4	60.5	46.8
	16	109.2	88.4	87.4	68.0
	30½	106.6	88.9	117.7	85.8
	47	108.0	91.6	125.8	97.5
100	1¾	98.6	98.0	57.6	35.4
	4	100.0	82.4	61.6	42.9
	7¾	98.7	80.6	69.5	55.2
	16	109.2	96.2	103.2	80.8
	30½	102.2	98.0	114.5	87.0
	47	106.5	85.7	126.3	95.6
120	1¾	101.4	81.8	56.9	36.6
	4	105.5	75.0	74.4	45.8
	7¾	101.3	74.1	81.8	60.2
	16	105.0	80.8	99.1	93.8
	30½	79.8	69.8	80.4	81.4
	47	96.5	71.2	147.6	110.9
140	1¾	101.3	74.8	65.0	37.9
	4	104.0	81.1	81.8	49.3
	7¾	86.0	79.8	139.1	64.6
	16	93.4	87.5	104.0	76.5
	30½	98.7	89.6	129.7	94.1
	47	86.1	75.0	126.2	55.8

these temperatures. No cross links were formed in their esterification procedure, however. When phthaloyl chloride replaced the anhydride, cross links did result.

In this part of the work, phthaloylation of wood was first attempted with phthaloyl chloride and pyridine catalyst. When this proved unsuccessful because of heavy degradation of the wood, esterification was tried by using phthalic anhydride in conjunction with pyridine or dimethylformamide.

EXPERIMENTAL

Treatments with Dimethyl Phthalate as Solvent

In this phthaloylation procedure, the general method was to dissolve the phthalic anhydride in dimethyl phthalate, and add pyridine and zinc chloride as acylating catalysts. The oven-dry samples were placed in the solution maintained at the desired temperature for the desired length of time, after which time they were removed, dried at 105° C. for 24 hours, and cooled in a desiccator. After this, the samples were weighed and measured. Soak-testings for antishrink efficiency usually followed.

Some of the factors affecting the reaction were studied.

Effect of Treating Time: A solution of phthalic anhydride (100 g.) in dimethyl phthalate (100 ml.) containing pyridine (10 ml.) and fused zinc chloride (2 g.) was heated to reflux. Blocks of oven-dry black spruce, *Picea mariana* (Mill.) B.S.P., measuring two inches (in the fiber direction) by 0.5 inch by 0.3 inch, were placed in this solution for different periods of time (see Table 1). After treatment, they were dried, weighed, and measured. They were then soak-tested for antishrink efficiency.

Effect of Concentration of Treating Solution: Oven-dry black spruce blocks similar to those above were placed in refluxing solutions of phthalic anhydride in dimethyl phthalate and pyridine, the concentrations of these solutions being shown in Table 1. After a treating time of 22 hours, the blocks were removed from the solutions and dried. When weighed and measured, they were soak-tested.

Effect of Reaction Temperature: Oven-dry black spruce blocks were placed in solutions of phthalic anhydride, dimethyl phthalate, pyridine and zinc chloride of the concentration mentioned above. The temperatures at which these solutions were maintained are shown in Table 1. After 24 hours of treatment, the blocks were dried, weighed, and measured. Soak-testing followed.

Treatments with Dimethylformamide as Solvent

Study of the Effect of Treating Time and Reaction Temperature upon the Antishrink Efficiency and Weight Increase of Balsam Fir: For this study, blocks of balsam fir, *Abies balsamea* Mill., measuring two inches (in the fiber direction) by 0.5 inch by 0.3 inch, were used. They were swollen in dimethylformamide (DMF) for 24 hours, and were found to have absorbed 2.8 g. of DMF per block. The swollen blocks were placed in solutions of phthalic anhydride (100 g.) in DMF (100 ml.), each solution maintained at a different temperature according to Table 2. Treating times were also varied as shown in Table 2. After treatment, the blocks were dried in an oven at 105° C for 24 hours. They were then cooled, weighed, and measured. The blocks then underwent an 8-hour soak-testing, were dried, and resoak-tested. By determining the antishrink efficiencies with each soak-testing, an estimation may be had of the permanency of the dimensional stability imparted by this phthaloylation method.

Study of the Permanency of the Antishrink Effciency: Balsam fir blocks of above dimensions were swollen in DMF for 24 hours and then placed in a solution of phthalic anhydride (100 g.) in DMF (100 ml.) and heated at 80° C. for 16 hours. After this time they were dried for 24 hours, cooled, weighed, and measured. The blocks were cut into halves, about one inch by 0.5 inch by 0.3 inch. One half was used for ester stability studies as described below, while the other half was used for permanency studies (Fig. 3) by a series of soakings and leachings according to the following technique:

First soak: The blocks were soaked in distilled water for eight hours. After being measured, they were dried at 105° C. for 20 hours.

Second soak: The blocks were heated to 115° C. for 17 hours under reduced pressure to remove unreacted phthalic anhydride by sublimation; then they were cooled, measured, and soaked in distilled water for eight hours. The water-soaked dimensions were taken.

Third soak: After their second soak, the blocks were dried at 130° C. for 18 hours. When cooled, they were measured, and soaked for eight hours in distilled water. The water-soaked dimensions were again taken.

Fourth soak: After being dried at 115° C. for 18 hours, the blocks were soak-tested in an acid solution with a pH 1.

Fifth soak: The blocks were dried at 115° C. for 18 hours and soak-tested again, this time in a sodium hydroxide solution, pH 14.

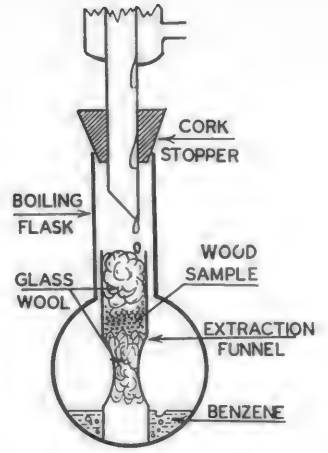

Fig. 1.—Apparatus for the extraction of phthalic anhydride from phthaloylated wood.

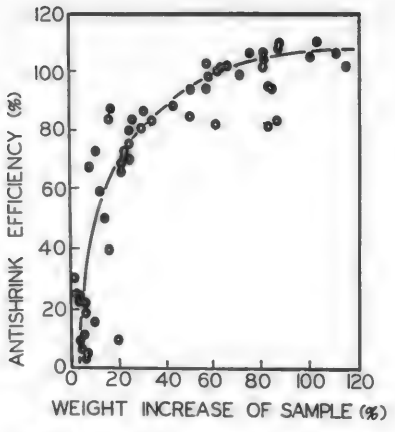

Fig. 2.—Relation between the weight increase of balsam fir blocks upon phthaloylation and their antishrink efficiency.

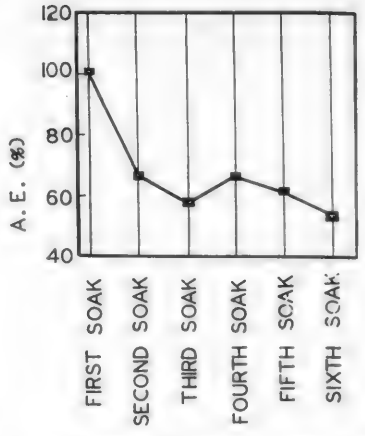

Fig. 3.—Effect of soaking upon the antishrink efficiency (A.E.) of phthaloylated balsam fir blocks.

Sixth soak: The blocks were leached in running water for four days and nights, then oven-dried and measured. They were finally soaked in distilled water for eight hours and their antishrink efficiencies determined.

Study of the Heat Stability of the Phthalic Acid Esters in Wood: Blocks of phthaloylated balsam fir were ground in a Wiley mill to pass a 20-mesh screen. The particles were well blended to give a homogeneous mixture. Half-gram samples were accurately measured into specially designed extraction funnels (Fig. 1). The funnels were placed in 200 ml. distilling flasks, the necks of which were stuffed with glass wool. The flasks were heated to 130° C. for the periods of time shown in Table 3. The necks of the flasks were kept cool to catch any sublimate that might have formed. The contents of the flasks were then extracted with benzene in the extraction funnel and analyzed for phthalic anhydride and phthalic acid ester according to the method described by Downs and Stupp (3).

Table 3.—ANALYSIS OF PHTHALOYLATED BALSAM FIR AFTER BEING HEATED AT 130° C.

Heating time Hours	Phthalic anhydride Calculated as phthalic acid %	Phthalic acid ester Calculated as phthalic acid %
0	23.7	4.4
0	24.5	
2	13.5	7.4
4	10.4	9.5
24	7.3	11.4
45	6.4	10.6

Humidity Studies

Blocks of balsam fir were phthaloylated to between 19 and 32 per cent. These underwent humidity studies so as to ascertain the mechanism by which dimensional stability is imparted by phthaloylation. The results are shown in Figs. 4, 5 and 6.

Discussion

When dimethyl phthalate is used as the solvent for the phthalic anhydride with pyridine as the catalyst, maximum antishrink efficiencies are attained after 8 to 16 hours of treating at reflux. Even though the weight of phthalic anhydride introduced continues to increase after this time, no further increase in antishrink efficiency is observed. Table 1 shows that the preferred concentration of the treating solution is 20 to 30 grams of phythalic anhydride in 100 ml. of dimethyl phthalate. The optimum reaction temperature is 80° C. This agrees with the findings of Levey (6) in his work with cellulose. Higher temperatures increased the amount of phthalic anhydride introduced, but the antishrink efficiency decreases, probably because of degradation of the wood. In all cases, the reduction in water absorptivity of the phthaloylated wood (which is a measure of its hygroscopicity) is less than the reduction in swelling, but nevertheless, parallels it.

Since dimethylformamide is superior to dimethyl phthalate as a solvent for phthalic anhydride and as a swelling agent for wood, it replaced the dimethyl phthalate in subsequent work. By using it, very high antishrink efficiencies were obtained even after only a very short treating time (Table 2) at a relatively low temperature (80° C.). Increased treating time, and, up to a point, increased temperatures brought about increased antishrink efficiencies. However, at 120° C. and above, degradation of the wood offset the improvement that resulted from the introduced phthalic anhydride.

Normally, as the amount of phthalic anhydride introduced into the wood increases, the antishrink efficiency imparted to the wood increases to a maximum of 106 per cent at about 75 per cent weight increase of the wood (that is, 75 grams of phthalate in 100 grams of wood). This is seen in Fig. 2.

An antishrink efficiency of over 100 per cent means that the treated sample shrinks when soaked in water. This is possible when the wood is bulked beyond its water-swollen dimensions by a water-leachable substance. In the present case, the dimethylformamide swelled the wood beyond the water-swollen dimensions, and then bulked it with phthalic acid ester and free anhydride. Thus the oven-dry treated volume of the wood was greater than its water-soaked volume. When the treated sample was soaked in water, the slightly water-soluble phthalic anhydride was leached and the sample began to shrink to its water-swollen dimensions. Hence the wood shrank when soaked in water.

During soak-testing, not only the anhydride was leached. As the water used for soak-testing evaporated, two types of crystals were recovered. One was crystallized from benzene and found to have a melting point of 128–130° C. This was phthalic anhydride. The second was dissolved in dilute sodium hydroxide and was reprecipitated by slowly adding hydrochloric acid. The reprecipitated crystals melted at 210° C. The product was soluble in acetone, ethanol, and dilute ammonium hydroxide; insoluble in benzene and toluene. It was thought to be a cellulose phthalate (7).

When phthaloylated blocks were soak-tested, the weight of introduced phthalic anhydride was greatly reduced. The studies of the permanency showed that the antishrink efficiency also dropped off rapidly to between 50 and 70 per cent. Neither further leaching nor the pH of the water used for soak-testing seemed to influence subsequent antishrink efficiencies greatly.

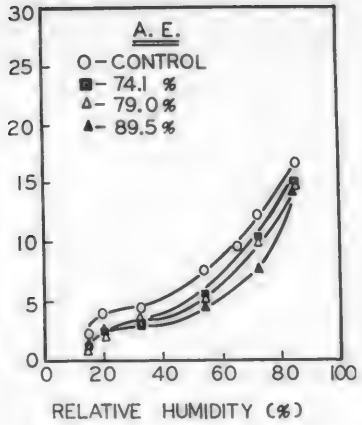

Fig. 4.—Relation between relative humidity and the moisture content of phthaloylated balsam fir blocks of various antishrink efficiencies (A.E.).

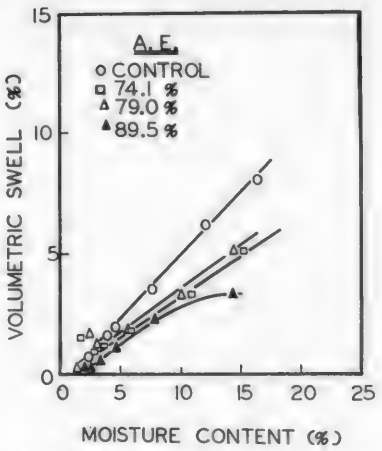

Fig. 5.—Relationship between moisture content and volumetric swelling of phthaloylated balsam fir blocks of various antishrink efficiencies (A.E.).

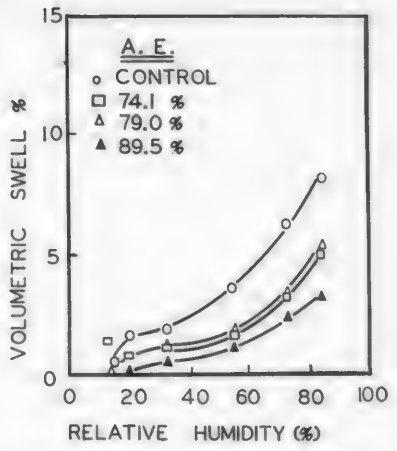

Fig. 6.—Relation between relative humidity and volumetric swelling of phthaloylated balsam fir blocks of various antishrink efficiencies (A.E.).

Whereas Nikitin and others (8) found the acid form of cellulose phthalate unstable to heat, this present work has shown that the amount of ester increases to a maximum after 24 hours as the wood-phthalic anhydride-phthalic ester system is heated at 130° C.

Humidity studies have shown that phthaloylated wood exhibits decreased hygroscopicity over the entire range of humidities (Fig. 4), the amount of decrease depending upon the amount of introduced phthalic anhydride. Since swelling depends upon the moisture content of the treated samples (Fig. 5), reduced hygroscopicity must account for some of the stability imparted to the dimensions of phthaloylated wood.

Fig. 5 also gives an indication of the other part of the mechanism of dimensional stabilization of the phthaloylated wood. At low moisture contents, the per cent swelling of the treated blocks is about the same as for the untreated control. Between 5 and 12 per cent moisture, swelling is contained and the curves level off. The greater the phthalyl content, the less is the swelling permitted. These data substantiate the theory that at least part of the dimensional stability imparted to wood by phthaloylation is attained through bulking.

Fig. 6 shows what happens dimensionally to a piece of phthaloylated wood during humidity changes. At low humidities, the phthaloylated wood exhibits reduced swelling because of decreased hygroscopicity. At the higher humidities, the reduction in swelling is much greater because of the combination of two effects, namely reduced hygroscopicity and the bulking effect.

Conclusion

Phthaloylation imparts to wood the highest degree of dimensional stability yet observed, but because of the partially temporary character of the dimensional stability it imparts, it could find only limited use in cases where the wood is subjected to periods of soakings, for example, as the hulls of boats or for the external uses where falling rain could leach the phthalic anhydride. Perhaps a more complete study of the phthaloylation reaction would reveal conditions whereby the dimensional stabilization could be made more permanent.

On the other hand, where the wood is subjected to normal changes in atmospheric humidity but not to soaking, phthaloylated wood could be used to advantage as a dimensionally stable product. The reduced hygroscopicity of the wood would prevent it from taking too much moisture from the atmosphere, which might cause leaching, as is the case with butylated wood (9), and woods impregnated with salts (11) and sugars (12).

GENERAL CONCLUSIONS ARISING FROM PARTS I TO V

Summing up, the general results of this series of papers show that the most significant difficulty encountered in the study was the varying degree of degradation of the wood caused, possibly, by hydrogen chloride or pyridine hydrochloride formed in side reactions. Degradation is expected to be more pronounced in the first case, where a strong acid is formed. Thus, etherification by alkyl halides is a less convenient method of stabilization of wood than esterification by acid anhydrides. Results indicate that the degradation difficulty could be practically overcome in at least two cases by etherification. The ideal approach to chemical stabilization of wood therefore would be to employ reactants that do not yield harmful by-products. Such work is planned.

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Fungistatic Effectiveness and Leachability of Copper Abietate and Formate Preservatives[1]

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Copper abietate was found to protect wood against the copper-tolerant fungus *Poria monticola* and to be resistant to leaching by water. Copper formate, fixed in the wood by a steam treatment, was resistant to leaching but gave poor protection against *P. monticola*.

RECENT REPORTS HAVE INDICATED that copper formate and copper abietate are effective preservatives. Test-plot records for copper abietate or rosinate, dating from 1930, have given promising results (1),[2] although the absorption of preservative is not exactly known for the early tests. In later exposure tests, however, it was decided to treat to 0.04 pound of copper per cubic foot since this concentration of copper (as the naphthenate) was found to protect timbers against a moderate decay hazard. Copper abietate was also reported to be effective in protecting harbor installations against attack by marine borers (2).

Copper abietate can be prepared by several methods from wood rosin, which is principally abietic acid. The addition of copper sulfate to a solution of the saponified rosin yields a precipitate of copper abietate. It has also been found that the abietate is formed when copper metal or the oxide is exposed to a hot solution of rosin in benzene (1). A more direct method of preparation is to fuse equimolar quantities of copper acetate and wood rosin. The product is easily soluble in varsol and other hydrocarbons. Treated wood takes on the green color of the abietate, but has a clean dry surface.

Copper formate, because of its solubility in water, would be expected to be an ineffective wood preserving chemical. Smith and others (3) found, however, that a steam treatment caused the copper of the copper formate to become firmly fixed in wood; after several hours of steaming at 108–125° C., the green color of the treated wood was lost as the copper formate was converted into a compound resistant to leaching. Evidence was presented that indicated the formation of a copper-cellulose complex (3, 4). Other workers have also found evidence for the existence of a copper-cellulose complex (5).

Several species of wood in which copper had been fixed were found to resist attack by *Limnoria* and *Teredo* in sea water (3). Resistance against attack by several wood-destroying fungi was also found, but the copper-tolerant fungus *Poria monticola* was not employed.

Since the effectiveness of copper abietate as a wood preservative has not been investigated by the soil-block method, and since the resistance of wood, in which copper formate is fixed, against decay by a copper-tolerant fungus is not known, soil-block tests with *P. monticola* were performed with both preservatives. The leachability of each compound was also studied.

A number of posts of several species of wood have also been treated with copper abietate and fixed copper formate. They are being placed in a test-plot and will be reported upon as the results become available.

Experimental

Preservatives: Commercial copper formate containing26.8 per cent copper by weight, was used[3]; the copper abietate, not being commercially available, was prepared from wood rosin.

Rosin was dissolved in an equivalent quantity of 20 per cent sodium hydroxide at about 50° C. The solution was diluted to about 5 per cent sodium rosinate concentration, and an equivalent quantity of 5 per cent aqueous copper sulfate was added with stirring. The solution was then filtered and the precipitate washed with water and air-dried.

The dry precipitate was dissolved in varsol, and the solution was filtered to remove traces of copper hydroxide. The copper abietate contained 6.4 per cent copper by weight.

Soil-Block Tests: Cubes of red pine sapwood, ¾ inch on the edge, were employed. Two series of blocks were impregnated with a graded series of concentrations of the preservative as recommended in A.S.T.M. D 1413 56T. Varsol solutions of copper abietate and aqueous solutions of copper formate were used for the impregnations. Analyses of a number of blocks showed that the amount of copper abietate in the blocks agreed with the amount calculated from the observed retention of the solution by the blocks. *More copper formate, however, entered* the blocks than the amount calculated from the uptake of treating solution of known concentration. The average amount was 1.16 times that calculated. Apparently there is a positive sorption of copper formate by wood.

After the solvent had evaporated from the abietate-treated blocks, the treated and control blocks were subjected to decay by *P. monticola* by the standard method (A.S.T.M. D 1413 56 T). The jars used, however, were of 16-ounce capacity instead of the 8-ounce jars recommended. The sterilization of the abietate blocks was accomplished by the 20-minute steaming recommended in the above method. The formate blocks, however, had to be given a more severe treatment in order to fix the copper; they were steamed for 3 hours at 121° C. (15 psi).

After three months, the blocks were removed from the jars and their weight losses determined.

Leaching: The leaching was exhaustive since it was intended to compare leachabilities rather than to attempt to reproduce leaching comparable to that found in natural conditions. The blocks were split longitudinally into matchstick-size pieces, which were extracted in a soxhlet apparatus for 24 hours with distilled water. The leached wood and the extracts were then analyzed for copper.

Two sets of twenty blocks impregnated to about 0.2 pound of copper per cubic foot were employed; the copper was present as copper abietate in one set and as copper formate in the other. The sets were subdivided into groups of four blocks, which were leached after being given the following heat treatments: control, no heat treatment; 3 hours dry heat at 121° C. and ½ hour, 1 hour, and 2 hours, respectively, in steam at 121° C. (15 psi.)

[1] A contributed paper (received Jan. 1958) from the Forest Products Laboratories of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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Mrs. Merrall received B. Sc. and M. Sc. degrees from Manchester University, England, in Botany and Mycology. She came to the Ottawa Laboratory in 1956, and returned to England in 1957.

[3] Obtained from the National Cylinder Gas Co., Chicago, Ill.

Table 1.—LEACHABILITY OF COPPER FORMATE- AND COPPER ABIETATE-TREATED BLOCKS AFTER HEAT TREATMENTS

Heat treatment	Copper formate		Copper abietate	
	Color	Leachability (as % of total copper)	Color	Leachability (as % of total copper)
o treatment	green	56.1	green	11.9
21°C, steam, ½ hr.	colorless	28.4	faint green	10.5
21°C. steam, 1 hr.	colorless	21.6	very faint green	----
21°C. steam, 3 hr.	colorless	19.0	colorless	11.2
21°C. dry, 3 hr.	colorless	46.9	green	8.7

Results and Discussion

Both the copper abietate- and copper formate-treated blocks lost their green color when heated in steam at 15 psi (121° C), but the color loss occurred in a much shorter time for the blocks treated with copper formate (Table 1). The copper abietate suffered no color loss in the dry heat, but the copper formate color disappeared in about 20 minutes. The leachability of copper from the blocks treated with abietate was unaffected by steaming and was less than in the blocks treated with copper formate, even after the fixing process. The color loss of the heat-treated copper abietate was probably due to a curing of the compound similar to that found with other metallic salts of fatty acids used as paint dryers.

The copper loss from the formate-treated blocks was high before heat treatment, but was lowered by the steaming. Dry heat at the same temperature on dry blocks did not fix the preservative; water, apparently, is necessary in the process.

The blocks treated with copper abietate were found to resist decay, but those treated with copper formate decayed readily at copper contents as high as 0.25 pound per cubic foot. The data are plotted in Fig. 1. The decay is expressed as the per cent of the decay of the controls.

The decay of the copper abietate-treated blocks when expressed in the form of the logistic function (6) is

$$l + 5 = 7.281 \log x + 13.319$$
$$\text{or } l = 7.281 \log x + 8.319$$

where l is the "logit" of the decay, q, which is expressed as the percentage of the decay found in the controls (7)

$$l = \ln \frac{q}{1 - q}$$

and x is the copper content in pounds per cubic foot. This function is plotted as the solid line in Fig. 1.

The retentions of copper required to reduce decay to several levels are given in Table 2. Doses greater than 0.136 pound per cubic foot, which reduces decay to 11.9 per cent of that of the controls, are seen from the plot to give little added effectiveness. This value, then, could be considered as close to the threshold value.

Some other compounds of copper have been found to give a degree of protection to wood similar to that of copper abietate. Toxic limits of 0.01 to 0.1 pound per cubic foot of copper as copper sulfate are given (8) for a number of fungi. Duncan and Richards (9) found that the threshold value of copper as copper naphthenate against decay by *P. monticola* was 0.055 pounds per cubic foot when applied to wood in a non-volatile vehicle, although in an investigation with other carriers, Duncan (10) found the threshold was above 0.065 pound per cubic foot. Cowling (11) found, by a modification of the agar-block decay test, that the threshold of copper as the naphthenate against decay by *P. monticola* was about 0.15 pound per cubic foot. He found, however, that chelated copper (copper-8 quinolinolate) was about five times more effective.

The results of the soil-block tests with fixed copper formate, however, do not indicate an approach to the threshold value even at 0.25 pound per cubic foot. An independent test with red pine sapwood stakes treated along with the posts also gave poor results (12). The stakes, which retained 0.147 pound of copper per cubic foot, were steamed at 121° C. for 4.5 hours. They were then cut into two sets of 2 cm. cubes; one set was leached (A.S.T.M. D 1413–56T) and the other left unleached. These blocks, along with a set of untreated controls, were tested for decay resistance against *P. monticola*. The treated blocks, both unleached and leached, exhibited a decay loss approaching that of the controls; the mean weight loss of the unleached blocks was 75 per cent and of the leached blocks was 87 per cent of that of the controls. The fixing of copper as copper formate in wood apparently leaves it in a state less poisonous to *P. monticola* than is found with copper in other forms. A clearer picture of the effectiveness of fixed copper formate should be obtained as the test-plot results become available.

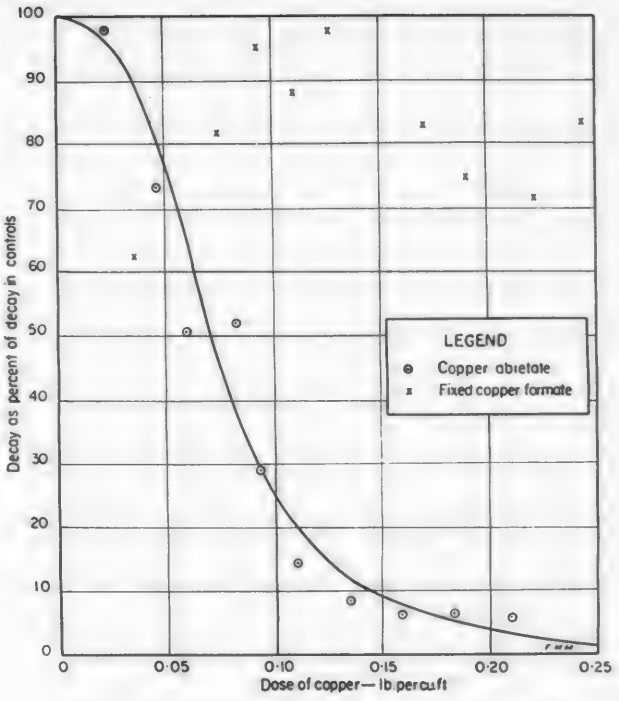

Fig. 1.—Fungistatic action of copper abietate and fixed copper formate against *Poria monticola*.

Table 2.—EFFECTIVENESS OF COPPER ABIETATE IN PREVENTING DECAY BY *PORIA MONTICOLA*

	Decay as % of controls	Dose lb. Cu/cu. ft.
0	50	0.072
1	26.9	0.099
2	11.9	0.136

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Relative Effectiveness of Several Oil-Soluble Wood Preservatives[1]

Condition of Dip-Treated Stake and Boardwalk Assemblies Exposed One Year to Decay and Termite Attack

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Stakes and boardwalk assemblies were exposed to decay and termite attack in field tests at Syracuse, New York, and Gainesville, Florida. After one year of exposure, important differences in effectiveness of the preservatives are apparent. No decay or termite attack developed in any pressure-treated wood at either region, while considerable decay and termite attack developed in dip-treated stakes.

PREDICTED FUTURE INCREASES in population and per capita consumption of wood products emphasize the importance of preservative treatments of wood for uses where deterioration hazards are high. Pressure treatment of wood with effective preservatives is an important industry and is universally accepted as providing superior protection to wood for uses with severe deterioration hazards.

Within recent years, simple treatments have been developed for wood protection in those uses where decay hazards are moderate or where pressure treatments are not possible or economically feasible.

Additional information is needed on the relative effectiveness of preservatives applied by dipping and on the periods of protection provided by such treatments, in various geographic regions.

A comprehensive review of the literature on laboratory and field evaluations of wood preservatives has been compiled by Colley (5)[3]. Data from an extensive program on the field evaluation of wood preservatives and preservative treatment methods have been reported periodically for many years by Blew of the U. S. Department of Agriculture, Forest Products Laboratory (3). Verrall (14, 15), Hicock and Olson (8), and Hirt (9) have presented information demonstrating the usefulness of simple treatments under some conditions of wood use. Significant contributions on the accelerated testing and evaluation of wood preservatives have been made by Sedziak (11) and Snoke (13).

In 1952, a research program was initiated for the U. S. Army Quartermaster Corps to study the absorption and penetration characteristics and the relative effectiveness of certain oil-borne preservatives applied by dipping. Results of the absorption and penetration phases of the program are published (4). This paper presents initial results on the relative effectiveness of the preservatives based on the condition of treated stakes and boardwalk units after a one-year exposure to wood decay fungi and termite activity in the vicinity of Gainesville, Florida, and to wood decay fungi in the vicinity of Syracuse, New York.

The specific objectives of this field preservative evaluation experiment are as follows:

a) To determine the relative effectiveness of five standard wood preservatives applied by dipping and pressure against wood decay fungi and termite activity.

b) To determine the effectiveness of dipping treatments in protecting stakes in soil contact and boardwalk assemblies exposed above the ground.

c) To determine the service life extensions obtained by the various preservative treatments of stake and boardwalk units exposed to wood decay hazards in two regions, Gainesville, Florida, and Syracuse, New York.

Materials and Methods

The experiment utilized a factorial design with 15 replications. Factors to be evaluated were kinds of preservatives, treatment methods, regions, and types of exposure. Three types of control specimens and an additional concentration of one preservative were included.

Test specimens 2 by 4 inches nominal by 18 inches (stakes) and 1 by 4 inches nominal by 18 inches (boards) were sawed from selected ponderosa pine (*Pinus ponderosa* Laws.). The specimens contained only sapwood and were selected to eliminate common defects such as stain, checks, and knots. Treating solutions were formulated as indicated in Table 1, which contains sources and descriptions of all solution components. Toxicant concentrations in the solutions for dip treatments were those commonly used or recommended by the manufacturers; toxicant concentrations in the solutions for the pressure treatments were formulated to yield toxicant retentions that would approximate estimated threshold values (Table 1) previously determined by using *Lenzites trabea* Pers. ex Fries and *Poria monticola* Murr. as the test fungi in the standard soil-block procedure (7). Each solution contained a resin and a wax as water repellents.

Two dip treatments and two pressure treatments were used. The dip treatments varied in time (15 seconds and 10 minutes) and the pressure treatments varied in the preservative carrier used. Carriers were a light oil, Solvasol No. 5, and a heavy oil, Acme B (see footnote 3, Table 1, for

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[2] Acknowledgement is extended to Prof. A. H. Bishop, N. Y. State U. of Forestry; Dr. A. M. Kaplan, Quartermaster Corps; Dr. J. B. Huffman, School of Forestry, U. of Florida; and to the School of Forestry, U. of Florida, for the test site.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

[4] The threshold value of a preservative is defined as the least amount of the preservative (based on retention in the wood) that will prevent decay by a given fungus under specific test conditions (6).

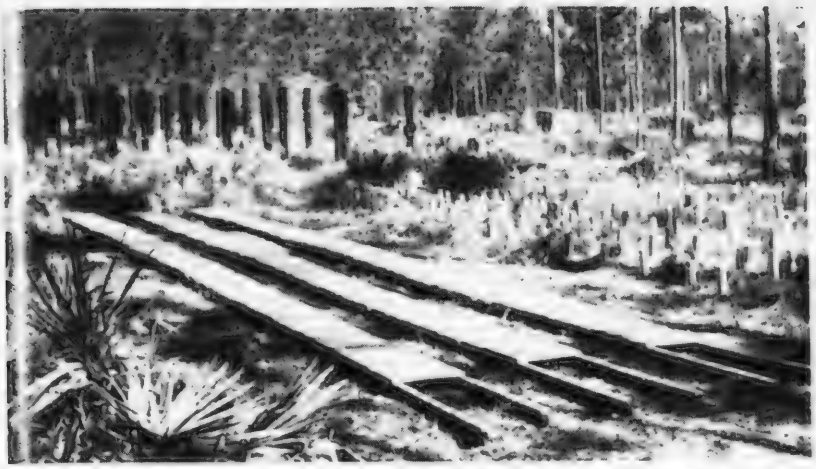

Fig. 1.—The boardwalk assembly and a portion of the stakes located in the vicinity of Gainesville, Florida.

descriptions and distillation ranges of these oils).

Test specimens for dip treatments were immersed in the treating solution for 15 seconds and 10 minutes. Pressure treatments were accomplished in a standard pressure cylinder. A pressure of 100 pounds per square inch for one hour was used in treating with the light-oil-carrier solutions; it was necessary to preheat the heavy-oil-carrier solutions to 150° F. and to use a pressure of 150 pounds per square inch for one hour to obtain approximately equivalent solution retentions.

All test specimens were weighed at an equilibrium moisture content of eight per cent immediately before treatment. Dip-treated specimens were allowed to drain for one minute and pressure-treated specimens for 12 hours prior to post-treatment weighings. Individual specimen retention values are based on these weights. Sufficient specimens were treated to permit rejection of those which displayed unusual absorptions, and to retain two specimens for each preservative treatment group for penetration determinations. Penetration determinations were made by chemical indicators and the specific procedures followed are detailed in a previous publication (4).

Table 1.—FORMULATION OF THE PRESERVATIVE SOLUTIONS USED IN THE DIP AND PRESSURE TREATMENTS

Preservatives[1] and controls	Estimated threshold retentions,[2] lbs./cu. ft.	Types of treatment	Concentration of components,[3] percent				
			Toxicant	Solvasol No. 5	Acme B	Paraffin	Resin
Pentachlorophenol[4]	0.19	pressure	1.0	88.8	----	1.6	8.5[5]
	0.19	pressure	1.0	----	88.8	1.6	8.5
		dip	5.0	83.1	----	1.6	10.0
Copper naphthenate (as metallic copper)	0.11	pressure	0.6	80.9	----	1.6	10.0
	0.11	pressure	0.6	----	82.4	1.6	8.5
		dip	2.0	63.4	----	1.6	10.0
		dip	1.0	75.9	----	1.6	10.0
Copper-8-quinolinolate	0.09	pressure	0.5	83.4	----	1.6	10.0
	0.09	pressure	0.5	----	84.9	1.6	8.5
		dip	1.0	78.4	----	1.6	10.0
Rosin amine D pentachlorophenate	0.65	pressure	3.3	80.2	----	1.6	10.0
	0.65	pressure	3.3	----	81.6	1.6	8.5
		dip	7.5	69.9	----	1.6	10.0
Zinc alkyl sulphonate	0.79	pressure	4.9	80.4	----	1.6	10.0
	0.79	pressure	4.0	----	81.9	1.6	8.5
	----	dip	5.0	78.4	----	1.6	10.0
Control (C3)	----	pressure	---	88.4	----	1.6	10.0
Control (C2)	----	dip	---	88.4	----	1.6	10.0

[1]Sources of the toxicants were as follows: pentachlorophenol, Dowicide 7 (95 per cent assay chlorinated phenols) from the Dow Chemical Co., Midland, Mich.; copper naphthenate, 7.9 per cent concentrate and zinc alkyl sulphonate, 50 per cent concentrate from Nuodex Products Inc., Elizabeth, N. J.; copper-8-quinolinolate, 10 per cent concentrate and rosin amine D pentachlorophenate, 50 per cent concentrate from Scientific Oil Inc., Chicago, Ill.

[2]Estimated threshold values for the various pressure treatments with preservatives were determined by the standard soil-block procedure (7) using *Lenzites trabea* and *Poria monticola* as test organisms. Actual average retentions obtained by the pressure and dip treatments are presented in Tables 2 and 3.

[3]All per cent concentrations are calculated on a weight basis; toxicant concentrations are expressed in terms of active toxicant since all preservative concentrates contained varying amounts of inerts; the resin is pentalyn H, a pentaerythritol ester of hydrogenated rosin (Hercules Powder Co.); paraffin is Fisher NF; Solvasol No. 5 is a Socony Vacuum Oil Co., Inc., product with approximately 20 per cent aromatic content and a flash point of 103°F., and with distillation range as follows: initial boiling point 320°F., 10 per cent distillation 328°F., 50 per cent distillation 338°F., 90 per cent distillation 356°F., end boiling point 383°F.; Acme B is a heavy oil product of Atlantic Oil Co., which meets AWPA specifications P-9, 1952 (2), and with distillation range as follows: initial boiling point 550°F., 10 per cent distillation 630°F., 50 per cent distillation F., 90 per cent distillation 780°F., end boiling point 820°F.

[4]Pine oil was added in amounts of 2 ml./60 gms. of solution, to solubilize the pentachlorophenol.

[5]The smaller percentage of resin (8.5 per cent) in some solutions resulted from an inadvertent shortage of resin during a final series treatment.

Penetrations obtained by the dipping treatments were comparable to data presented in Table 11 of the publication just cited. Complete preservative penetrations were obtained in all pressure treatments of boardwalk units and in the pressure treatment of the stakes with the following exceptions: two stakes treated with copper-8-quinolinolate in diluent Acme B had longitudinal penetrations of 6.3 inches and 5.3 inches, and radial penetrations of 0.5 inch; one stake treated with zinc alkyl sulphonate in Acme B had a longitudinal penetration of 4.1 inches and radial penetration of 0.6 inch; and one stake treated with zinc alkyl sulphonate in diluent Solvasol No. 5 had a longitudinal penetration of 2.4 inches and radial penetration of 0.4 inch.

Three types of control specimens were included and identified as follows: untreated, C1; dipped for 10 minutes in the light oil containing water repellents, C2; and pressure treated (100 psi for one hour) in a similar solution, C3.

Duplicates test plots were established at the Austin Cary Memorial Forest, managed by the School of Forestry, University of Florida, Gainesville, Florida, on January 25–27, 1956, and at the Forest Experiment Station managed by State University College of Forestry at Syracuse University on May 13–22, 1956. The installations were in light sandy soils under open coniferous stands. One randomly chosen test specimen from each of the 22 preservative by treatment method groups and the three control groups was randomly located within each of the 15 replicate groups for each type of exposure in each test plot. Stakes were placed nine inches in the ground in an upright position, spaced 2 by 3 feet according to the general procedures recommended by Standard M7 of the American Wood Preservers' Association for stake preservative evaluation tests (1). Boardwalk units were supported 3½ inches above the ground, separated from the creosote-treated 2 by 2¾ inch stringers by ¾ inch untreated strips (Figs. 1 and 2). The boards were spaced ¼ inch apart and nailed in position through holes bored prior to treatment.

The test plots will be inspected annually until failure is complete. Stakes and boards will be visually rated for extent of decay and termite attack and subjected to a low-stress strength test for failure determinations. The first-year inspections of the installations were made on February 1–3, 1957, and May 21–22, 1957, at Gainesville and Syracuse, respectively, and the data are presented in this report.

Evaluation System

Partial soil burial of the treated test stakes provides a severe decay and termite evaluation test. Since dipping treatments confer only moderate protection as compared to pressure treatments, it was desirable to use two rating methods. A visual rating method was developed to measure the short-term differences in the effectiveness of the preservatives, and a per cent failure rating method was designed for long-term comparisons of preservatives and treatments.

Individual stake and boardwalk units were rated visually, and were subjected to a low-stress strength test for failure determination where the degree of attack indicated potential failure. The two rating systems are described in detail.

Visual ratings: Visual observations of stakes in the installations compared with observations of the same stakes removed from the ground indicated that it was necessary to remove all stakes to estimate the stages of attack prior to complete failure. Stakes were loosened by slight rocking, and were removed without appreciable soil disturbance. After examination and rating, the stakes were replaced in their original positions and the soil was tamped carefully around them. Boardwalk units were removed briefly for study, and were then renailed in the same position.

A visual rating system was devised to express the amounts of decay and termite damage separately and also their combined effects on the sound volume of the test stakes and boardwalk units. Field experience indicated that estimates of the volume of decay or termite attack could not be reliably repeated at levels less than 1/5 of the specimen volume in the intermediate ranges.

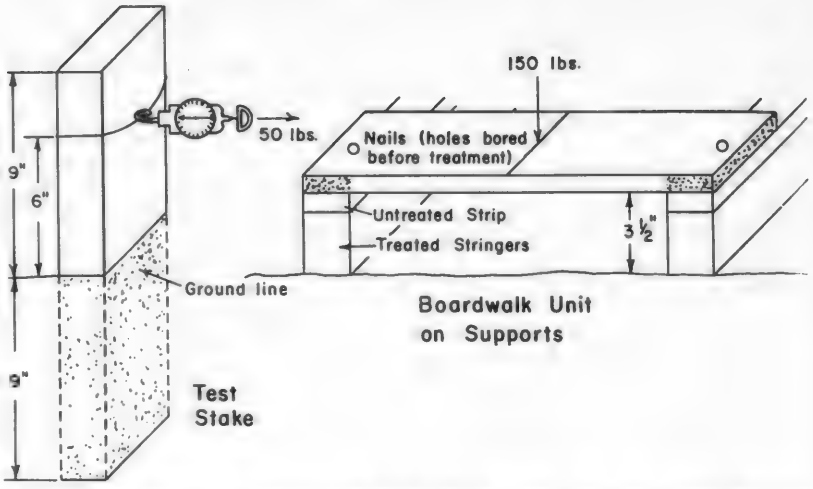

Fig. 2.—Strength tests were conducted on treated specimens that were severely attacked. Stippled areas indicate specimen volumes rated visually for amount of decay and termite attack.

Stake ratings were based on the proportion of the stake volume below the ground line that was destroyed. Boardwalk unit ratings were based on the proportion of the unit that was destroyed in direct contact with the stringer. The various stages of decay established were as follows:

0—no evidence of decay; sound
20—slight positive decay; less than 1/5 volume decayed
40—moderate decay; from 1/5 to 2/5 volume decayed
60—severe decay; from 2/5 to 3/5 volume decayed
80—extremely severe decay; from 3/5 to 4/5 volume decayed
100—complete decay; failure under low-stress test occurred generally in pieces with an excess of 4/5 volume decayed

The average of the various decay stages for the replications within a treatment group is the decay index presented in Tables 2 and 3.

The amount of termite attack in the stakes was estimated by means of a similar rating system based on the termite-attacked volume below the ground line. The effectiveness of the treatments against termites and decay fungi in the Gainesville installation was expressed by an estimated sound volume ranging from sound (100 per cent) to complete failure (0 per cent) in increments of 20 per cent. In this report, only average decay indices are presented since termite attack was limited to the Gainesville installations and occurred primarily within decayed zones and occupied small volumes.

Failure determination: When the condition at the ground line indicated potential failure, the stake was subjected to a load of approximately 50 pounds perpendicular to its longitudinal axis at a point six inches above the ground line (Fig. 2). Boardwalk units were subjected to a static load of 150 pounds at the center span (Fig. 2). The number that failed is expressed as a per cent of the number of replications (15) in the preservative by treatment method group and is termed failure per cent (Table 3).

Table 2.—A SUMMARY OF THE CONDITION AND AVERAGE PRESERVATIVE RETENTION FOR PRESSURE-TREATED STAKES AND BOARDWALK UNITS EXPOSED TO DECAY AND TERMITE ATTACK AT GAINESVILLE, FLORIDA AND TO DECAY ATTACK AT SYRACUSE, NEW YORK FOR ONE YEAR (1956–1957). THE TEST STAKES WERE PLACED PARTIALLY IN THE GROUND AND THE BOARDWALK UNITS WERE PLACED ON STRINGERS APPROXIMATELY 4 INCHES ABOVE THE GROUND

Preservatives[1] and controls	Estimated[2] threshold retentions, lbs./cu. ft.	Stakes: Retentions[3] lbs./cu. ft. Diluent Solvasol No. 5	Stakes: Retentions[3] lbs./cu. ft. Diluent Acme B	Stakes: Decay index[4] and termite index	Boardwalk assemblies: Retentions[3] lbs./cu. ft. Diluent Solvasol No. 5	Boardwalk assemblies: Retentions[3] lbs./cu. ft. Diluent Acme B	Boardwalk assemblies: Decay index[4] and termite index
Gainesville, Florida Installation							
Pentachlorophenol	0.19	0.130 (20)	0.138 (24)	0	0.138 (31)	0.225 (18)	0
Copper naphthenate (as metallic copper)	0.11	0.077 (12)	0.087 (29)	0	0.077 (23)	0.143 (12)	0
Rosin amine D pentachlorophenate	0.65	0.428 (16)	0.540 (14)	0	0.469 (27)	0.752 (13)	0
Copper-8-quinolinolate	0.09	0.063 (15)	0.081 (15)	0	0.063 (22)	0.098 (30)	0
Zinc alkyl sulphonate	0.79	0.420 (21)	0.627 (16)	0[5]	0.558 (19)	0.839 (13)	0
Control (C3)				0			0
Syracuse, New York Installation							
Pentachlorophenol	0.19	0.139 (15)	0.146 (25)	0	0.131 (37)	0.178 (27)	0
Copper naphthenate (as metallic copper)	0.11	0.077 (14)	0.082 (27)	0	0.082 (12)	0.121 (18)	0
Copper-8-quinolinolate	0.09	0.064 (10)	0.091 (15)	0	0.064 (15)	0.093 (24)	0
Rosin amine D pentachlorophenate	0.65	0.454 (17)	0.510 (19)	0	0.503 (24)	0.767 (12)	0
Zinc alkyl sulphonate	0.79	0.414 (24)	0.597 (21)	0	0.521 (17)	0.818 (13)	0
Control (C3)				0			0

[1]Compositions of the preservative solutions are presented in Table 1.
[2]Estimated threshold values for the various preservatives were determined by standard soil-block procedures (7) using *Lenzites trabea* and *Poria monticola* test fungi.
[3]Average retentions of active toxicant are based on 16 samples for each preservative and diluent. The numbers in parentheses are the coefficients of variation presented to indicate variation in toxicant retentions (12).
[4]An average of the decay stages or termite stages for the 15 replications in each preservative by treatment group.
[5]Slight decay developed at the ground line in a single specimen (diluent Solvasol No. 5).

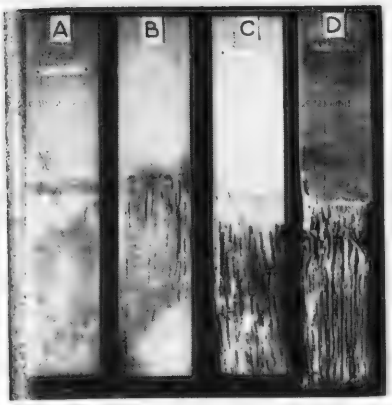

Fig. 3.—Condition of various stakes after a 1-year exposure near Syracuse, N. Y. A. Sound stake, pressure-treated; B. A dip-treated stake showing early stages of decay at ground line (decay stage 20); C. a dip-treated stake showing severe decay caused by a brown-rot fungus (decay stage 80); D. a control stake (C1) decayed by a white-rot fungus, which failed during the strength test.

General observations on kinds of decay, types of mycelial mats, relation between termite attack and decay, location of failures, and preservative characteristics were recorded. Average indices of condition and per cent failure were calculated for all preservatives and treatments.

Results

The amounts of decay and termite attack for the stakes and boardwalk units classified by preservatives, treatment methods, types of exposure, and regions, are summarized in Tables 2 and 3.

No decay or termite attack developed in any of the stakes that were pressure treated with the various preservatives to approximate threshold retentions, with one exception (Table 2).

No visible decay or termite attack developed in the controls or specimens treated by dipping or pressure during the one-year exposure of the boardwalk installations in the two test regions.

Decay in the two regions was surprisingly uniform, as is indicated by average decay indices of 51 and 57 for Gainesville and Syracuse, respectively, and by comparable amounts of decay in the untreated controls. The order of effectiveness of the preservatives was also similar for the two regions (Table 3). Data on average precipitations and temperatures during the test period compared to 10-year averages in the two regions suggest normal conditions.[5]

Major differences in the decay flora of the two regions were evident. Seventy-seven per cent of the decayed test stakes in Gainesville contained white rots, while 94 per cent in Syracuse contained the brown-rot type Fig. 3). Stakes in each region commonly contained both types of rots.

Extensive decay and some termite damage developed in many of the dip-treated stakes at the Gainesville test site, and equally severe decay damage occurred in many of the dip-treated stakes at the Syracuse test site (Fig. 3).

Large variation occurred in the protection provided by the two dip treatments and by the various preservatives. In both regions, the 10-minute dip was more effective than the 15-second dip.

The preservatives are arranged in order of effectiveness for each region, since the Gainesville test site involves both decay and termite attack and the Syracuse test site decay only.

At the Gainesville test site decay greatly exceeded termite damage. Cases of termite attack with no decay were limited (less than two per cent), whereas cases of extensive decay with no visible termite attack were common (30 per cent). Approximately 50 per cent of the stakes contained both decay and termite attack. In nearly all cases, termite attack was limited to the decayed volume of the stake. Preservative effectiveness ratings were based on decayed volumes only since termite attacks were limited generally to decayed wood and occupied limited volumes. Arrangements of the preservatives in the order of effectiveness were similar for termite damage and decay.

Differences between average decay indices for the preservatives were analyzed statistically by computing, for each region and treatment, a least

[5] U. S. Weather Bureau data are summarized as follows: Gainesville, total precipitation 49.38 inches in 1956, average annual precipitation 53.82 inches (1946–1956), average temperature 70.3° F. in 1956, average temperature 70.9° F. (1946–1956): Syracuse, total precipitation 42.01 inches in 1956, average annual precipitation 37.11 (1946–1956), average temperature 47.1° F. in 1956, average temperature 48.8° F. (1946–1956).

Table 3.—A SUMMARY OF THE CONDITION AND AVERAGE PRESERVATIVE RETENTION FOR DIP-TREATED STAKES AND BOARDWALK UNITS EXPOSED TO DECAY AND TERMITE ATTACK AT GAINESVILLE, FLORIDA AND TO DECAY ATTACK AT SYRACUSE, NEW YORK FOR ONE YEAR (1956–1957). THE TEST STAKES WERE PLACED PARTIALLY IN THE GROUND AND THE BOARDWALK UNITS WERE PLACED ON STRINGERS APPROXIMATELY 4 INCHES ABOVE THE GROUND.

	Stakes 15-Second dip[2]				Stakes 10-Minute dip[2]				Boardwalk assemblies			
									15-Second dip[2]		10-Minute dip[2]	
Preservatives[1] and controls	Decay index	Failure, per cent	Retention lbs./cu. ft.	Preservatives[2] and controls	Decay index	Failure, per cent	Retention, lbs./cu. ft.		Decay index and termite index	Retention lbs./cu. ft.	Decay index and termite index	Retention, lbs./cu. ft.
Gainesville, Florida Installation												
5 per cent pentachlorophenol	20	0	0.024 (17)	2 per cent copper naphthenate (as metallic copper)	7	0	0.017 (26)		0	0.015 (16)	0	0.025 (17)
2 per cent copper naphthenate (as metallic copper)	25	0	0.011 (18)	5 per cent pentachlorophenol	11	0	0.047 (15)		0	0.043 (18)	0	0.071 (17)
1 per cent copper naphthenate (as metallic copper)	51	13	0.005 (11)	7.5 per cent rosin amine D pentachlorophenate	11	0	0.069 (13)		0	0.052 (16)	0	0.095 (17)
7.5 per cent rosin amine D pentachlorophenate	52	20	0.041 (15)	1 per cent copper naphthenate (as metallic copper)	35	13	0.009 (13)		0	0.008 (15)	0	0.013 (21)
1 per cent copper-8-quinolinolate	73	33	0.005 (20)	1 per cent copper-8-quinolinolate	49	13	0.008 (27)		0	0.008 (26)	0	0.012 (16)
5 per cent zinc alkyl sulphonate	83	53	0.028 (16)	5 per cent zinc alkyl sulphonate	68	33	0.051 (16)		0	0.044 (22)	0	0.071 (22)
Control (C2)	88	67		Control (C2)	88	67					0	
Control (C1)	99	100		Control (C1)	99	100			0		0	
Syracuse, New York Installation												
5 per cent pentachlorophenol	36	7	0.027 (14)	5 per cent pentachlorophenol	11	0	0.044 (21)		0	0.039 (17)	0	0.072 (19)
2 per cent copper naphthenate (as metallic copper)	52	20	0.011 (23)	2 per cent copper naphthenate (as metallic copper)	15	0	0.018 (12)		0	0.016 (20)	0	0.026 (16)
1 per cent copper-8-quinolinolate	56	20	0.005 (15)	7.5 per cent rosin amine D pentachlorophenate	25	0	0.070 (14)		0	0.050 (12)	0	0.090 (24)
7.5 per cent rosin amine D pentachlorophenate	57	7	0.041 (16)	1 per cent copper-8-quinolinolate	39	0	0.009 (25)		0	0.007 (21)	0	0.013 (20)
1 per cent copper naphthenate (as metallic copper)	57	27	0.005 (15)	1 per cent copper naphthenate (as metallic copper)	48	7	0.009 (14)		0	0.007 (15)	0	0.012 (13)
5 per cent zinc alkyl sulphonate	84	67	0.027 (14)	5 per cent zinc alkyl sulphonate	80	40	0.049 (13)		0	0.035 (26)	0	0.072 (25)
Control (C2)	85	60		Control (C2)	85	60					0	
Control (C1)	97	87		Control (C1)	97	87			0		0	

[1] Compositions of the preservative solutions are presented in Table 1.

[2] An average of the decay stages, failure per cent, and, in two cases where the heading so indicates, the termite stages for the 15 replications in each preservative treatment group. The numbers in parentheses after the retentions are the coefficients of variation presented to indicate variation in toxicant retentions (12).

difference that was significant at the five per cent level. The least difference was compared with all possible differences between average decay indices (12). At the Gainesville site, 2 per cent copper naphthenate, 5 per cent pentachlorophenol, and 7.5 per cent rosin amine D pentachlorophenate gave the greatest protection. One per cent copper naphthenate and one per cent copper-8-quinolinolate gave intermediate protection. Five per cent zinc alkyl sulphonate gave the least protection. For the 15-second and 10-minute treatments, differences between average decay indices greater than 24 are significant (Table 3).

At the Syracuse site, 5 per cent pentachlorophenol, 2 per cent copper naphthenate, and 7.5 per cent rosin amine D pentachlorophenate gave the greatest protection. One per cent copper naphthenate and one per cent copper-8-quinolinolate gave intermediate protection. Five per cent zinc alkyl sulphonate again gave the least protection. Differences between decay indices in excess of computed least differences of 31 and 21 for the 15-second and 10-minute treatments, respectively, are significant (Table 3).

All 15 control specimens C1, untreated, at the Gainesville site and 13 of the 15 at the Syracuse site failed during the first year of exposure. Control specimens C2, treated by a 10-minute dip in the Solvasol No. 5 containing water repellents, gave decay indices of 88 and 85 at Gainesville and Syracuse, respectively. Control specimens C3, pressure treated in the Solvasol No. 5 containing water repellents, gave lower decay indices of 49 and 11 at Gainesville and Syracuse, respectively.

The initial point of attack and the location of major deterioration in stakes at both sites appeared to be generally a few inches below the ground line (Fig. 3).

An unidentified fungus with a characteristic black appressed mycelium on the stake surface was associated frequently with copper-containing preservatives at both sites.

Discussion

It is emphasized that this progress report is based largely on visual ratings of treated and untreated wood test specimens after a one-year exposure to decay and termite attack. It is planned that the experiment will continue for a minimum period of five years. The per cent of specimens that fail within a treatment group is believed to be the most useful measure of treatment and preservative effectiveness over a period of years. The average decay indices presented, however, yield useful early estimates.

The absence of decay or termite attack in the pressure-treated stakes as compared with extensive failures in the dip-treated stakes underlines the importance of adequate pressure treatments with effective preservatives where wood is to be subjected to a severe decay hazard, such as direct soil contact. Pressure- and dip-treatment effectiveness in these data may be explained by differences in the penetration of the preservatives. In general, the pressure treatments used in these experiments gave complete penetration of the specimens, whereas the 10-minute dip treatments produced a relatively thin shell of treated wood around the specimen. The depth of this shell did not exceed two mm. in the tangential direction. Even though considerably higher preservative concentrations were used in the dip treatments, apparently the continuity of the treated shell was easily disrupted by checks, which were the result of drying stresses that developed at the ground line, or from other soil effects. Recent observations of the test installations after two years of exposure indicated that essentially all dip-treated stakes, regardless of preservative type, had failed as compared to failures within one year for untreated control stakes.

The great difference in decay hazard between wood in direct contact with the soil as compared to wood exposed a few inches above the ground is indicated by the absence of decay or termite attack in any of the boardwalk units. Recent observations of the installations after two years of exposure indicated considerable failure of control specimens in the boardwalk at Gainesville.

The apparent uniformity of the decay hazard of wood in soil contact in the northern and southern installations is surprising in view of the longer southern growing season. Weather records indicated that normal precipitations and temperatures prevailed in the two regions during the test period. This suggests that either decay develops more rapidly during the shorter northern growing season or that observed differences in the white and brown rot fungus flora may affect the rate of decay. In general, specimens severely decayed with brown rots appeared to break more readily than specimens similarly decayed with white rots. It was observed that many brown rots were concentrated within the specimen at the ground line, whereas white rots were generally uniformly distributed throughout the buried portions of the specimens. Where the two types of decay were associated within the same specimen, the brown rot was concentrated at the ground line and the white rot was limited to the base of the stake.

Termites were present throughout the southern test area. It is possible that termite attack preceded decay, and that subsequent decay then obliterated the signs of initial termite attack. However, the results stated previously suggest that termite attack usually followed decay in these installations. The significance of the fact that termite attack appeared limited to badly decayed stake volumes is uncertain.

No explanation is known for the rather surprising decay and termite resistance of the stakes in the control series (C3) that were pressure treated with Solvasol No. 5 and water repellents. At inspection, many of these stakes were much heavier and wetter than the average.

The considerable variation observed in the effectiveness of a preservative within a replication, ranging in some cases from sound to failure, and the relatively high coefficients of variation reported for the retentions, emphasize the need for considerable replication in field preservative evaluation experiments.

Conclusions

The data presented appear to warrant the following conclusions:

1. Important differences in the effectiveness of the preservatives based on one-year exposures at the Gainesville and Syracuse test sites are apparent. Five per cent pentachlorophenol, 2 per cent copper naphthenate, and 7.5 per cent rosin amine D pentachlorophenate appeared to be the most effective preservatives in both regions. One per cent copper naphthenate and one per cent copper-8-quinolinolate gave intermediate protection. Five per cent zinc alkyl sulphonate was the least effective preservative in both regions.

2. No decay developed in pressure-treated stakes in contact with the ground with one exception, whereas extensive decay developed in dip-treated stakes. With the more effective preservatives, the 10-minute dip-treatment gave better protection than did the 15-second dip treatment.

3. The results emphasize the striking difference between the severe decay hazard of wood in contact with soil and the limited decay hazard of wood exposed above the ground. No decay developed in untreated control specimens in boardwalk units located a few inches above the ground, while many of the dip-treated specimens and most untreated control specimens failed completely in contact with the ground.

4. The decay hazards for wood in contact with soil for the two regions appeared to be similar, as was indicated by average decay indices of 51 and 57 for Gainesville and Syracuse, respectively.

5. Major differences in the decay fungi of the two regions were obvious. Seventy-seven per cent of the decayed test stakes at Gainesville contained the white-rot type, while at Syracuse 94 per cent contained brown rot.

6. The pattern of termite and decay attack in these test stakes suggests that, in the Gainesville installation, termite attack was minor as compared to decay, and occurred almost entirely within decayed wood.

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A Review of Methods for the Sampling of Timber[1]

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Efficient methods for the sampling of timber are discussed, and comparisons are made with those methods specified in various timber testing standards. The importance of a random process of selection is emphasized. Accurate estimates of species properties depend mainly on the number of trees properly sampled and not on the total number of specimens tested. The most efficient, and often most economical, sample consists of only one specimen from each tree; such a sample has been found satisfactory in practice.

THE DETERMINATION OF THE MECHANICAL or other properties of timber presents a sampling problem. Timber is a variable material—much more so than most other structural raw materials—so that enough of the material needs to be tested to give accurate estimates and an indication of the variability. On the other hand, testing facilities and the cost of timber set a limit to the amount that can practicably be tested. It is therefore desirable that, in testing timber, sampling methods that give the greatest accuracy at minimum cost be employed. The purpose of this paper is to discuss some efficient methods for the sampling of timber, and to compare these with the methods that have been specified by various authorities as standards.

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1. Introduction

It is not intended in this paper to develop the mathematics of sampling or to discuss efficiency in other than a qualitative way. Such discussions have been published elsewhere, for example, the excellent handbooks of Cochran (1953) and Yates (1953).

A detailed review of the applications of statistical methods to industrial standardization is given in the Bulletin of the International Statistical Institute, Volume 34, Part 4, Section II, (pages 253 to 383). A modified version of the report on statistical techniques in American industry is given by Bicking (1954). Although many industries including the paper industry are discussed by Bicking, there is no mention of work done in the timber industry. Timber being a raw material and subject to considerable variation is, of course, less amenable than many other materials to standardization. This, however, makes it all the more necessary to choose efficient methods of standarization based on statistical sampling and not inefficient methods. Specific applications of statistics to sampling of timber for mechanical testing have been thoroughly discussed, and sampling procedures recommended, by Pearson (1952). A more elementary discussion has been given by Williams (1955). This paper will make use of the results given in Pearson's paper, to which reference should be made for details.

2. General Principles of Sampling

In sampling for species testing, the final unit is the individual test specimen but this is obtained only after several intermediate stages of selection. The specimen is selected from a stick sawn from a flitch which in turn has been cut from a log chosen from a particular tree in a selected locality. At every one of these stages, namely the locality, tree, log, flitch and stick stages, an objective sampling procedure

should be adopted to select the component for the next stage. Each selected component should be regarded as coming from the population of all such components which might possibly be cut or obtained from the unit of the previous stage. Thus, for example, a log would be regarded as composed of all the possible flitches which might be sawn from it.

It is by now a commonplace that any sample needs to be selected in a random manner, that is, in such a way that any member of the population under consideration has independently the same probability of inclusion in the sample as any other member. Failure to adopt a proper sampling procedure will not only lead to biased results, but will prevent valid estimates of sampling errors from being calculated, and consequently the accuracy of the calculated means and other statistics will be doubtful.[2]

The random sampling may be restricted, for instance by stratification of the population, each stratum being treated as a sub-population and randomly sampled. Unrestricted random sampling is seldom practicable, nor is it as accurate as stratified sampling if the strata can be so defined that they have less internal variation than the original population.

The initial problem in sampling a species is to decide the appropriate population of trees to be sampled, and this is not always easy. The most convenient population to sample comprises the trees at present being milled, but this is a population that will shortly cease to exist; the test results may not apply to timber of the species milled in a few years time, so a fresh sample may have to be taken at a later date. A more desirable population may comprise the trees to be felled within the next 10 or 20 years, but often not all such trees are accessible.

One aspect of timber sampling is often overlooked and yet vitally affects the validity of the final results. Trees growing within the same locality may be of the same or related parentage, and are often subject to similar growth conditions that may affect the properties of each tree in a similar manner, so that there will be a correlation between test results from trees in the same locality. Similarly there will be a correlation between results for specimens drawn from the same tree. The method of sampling and the analysis of the test data need to take these correlations into account.

The species should be sampled to cover the wide variation in growth conditions that usually occurs throughout its geographical range. This may be done by dividing the range into a very large number of areas, preferably of equal importance as regards present or estimated future production of sawn timber or other relevant consideration, and selecting by some random process a number of areas equal to the number of trees required. The areas should be sampled with replacement so that it would be possible for any area to be selected more than once, any such area then supplying more than one tree. Often a convenient method of selecting a sample in practice is to use existing administrative forest districts, allot them weights in accordance with their importance for the species to be sampled, and by a random process decide how many trees are to come from each district. Each district chosen to supply one or more trees would then be subdivided into smaller areas of roughly equal importance, and one or more chosen to supply trees. These areas themselves would probably be subdivided and the process repeated until the particular places are chosen from which each tree is to come.

Sampling errors may often be substantially reduced if a stratified random sample is practicable instead of the unstratified sample just described. This will be possible if the region in which the species grows can be subdivided into several localities between which there are marked differences in growth conditions but within which conditions are reasonably homogeneous. This procedure may be particularly suitable for plantation-grown material. Each such locality need not be a single compact area geographically but may comprise a number of scattered areas of similar growth conditions. Every locality should be sampled and should supply at least two, preferably more, trees because the standard error of the species mean may then be based on the variation within localities. These trees would be randomly selected within the locality.

Any sampling method, to be satisfactory, must take into account the practical problems of selecting the sample. These problems may impose restrictions but it is always feasible to devise a procedure which does not rely significantly on the judgment of the collector.

A suitable method of choosing a tree from an area being logged is for the collector to take the tree being felled at the time of his arrival. If no logging operations are in progress, then he might walk a random distance in a random direction, and then choose the nearest tree of the desired population.

If the tree is large enough to be sawn into several logs, then the log to supply a flitch would be selected by tossing a coin or using some other random process. The position in the log from which the flitch is to be cut should also be decided by a random process, although the shape of the log or the presence of gross defects may impose some restrictions. One such process is to draw a diametral line on the end of the log and to toss a coin to decide which half-log supplies the flitch. The chosen half, if large enough, may be further subdivided and a coin again tossed to decide the position of the flitch. A similar process may be adopted to determine the position of the stick from which the test specimen will be cut. Usually more than one stick is needed to supply one specimen for each kind of test. As far as possible, the layout of the different kinds of specimens in the sticks should be randomized, but the presence of defects often necessitates some compromise.

If more than one specimen for each kind of test is to come from a tree, it is not satisfactory to cut them from the same flitch. Each specimen should be selected by the same procedure as suggested above, quite independently of any other specimen. Thus if three specimens are required from the tree, then three flitches selected from random positions in the merchantable bole will also be required, unless the tree is small or the random process has indicated one flitch to supply more than one specimen.

3. Calculation of the Species Mean and its Standard Error for an Unstratified Sample

Two methods of analysis arise, depending on whether the sample was stratified or unstratified, that is, whether the geographical range was divided into a few homogeneous localities or not. Only the case of the unstratified sample is considered here because the procedure is simpler mathematically and the same conclusions arise for both cases. For a stratified sample, the species mean and its standard error are built up from

[2] It is sometimes claimed that, for a sample of trees to be truly representative of the species, it must possess some particular characteristic. For example, it might be specified that the sample trees should be of average girth or taken from a site of average growth conditions, or that the density of the sample should equal the average density of the species. More elaborately, the specification might call for the sample to include the range as well as the average of girth sizes, growth conditions or densities. There are several objections to this form of specification. Frequently personal judgment enters with consequential bias in the results, and valid estimates of sampling errors become impossible. The value of the characteristic chosen as the criterion of representativeness of the sample is itself open to doubt unless estimated from an objective sampling procedure. If the species average value of the characteristic is accurately known, then the average properties of a randomly selected sample can always be adjusted to this species average by means of a regression analysis. There is thus no need in practice for selectively sampling the material to conform to some pre-determined specification with its attendant uncertainties of estimation.

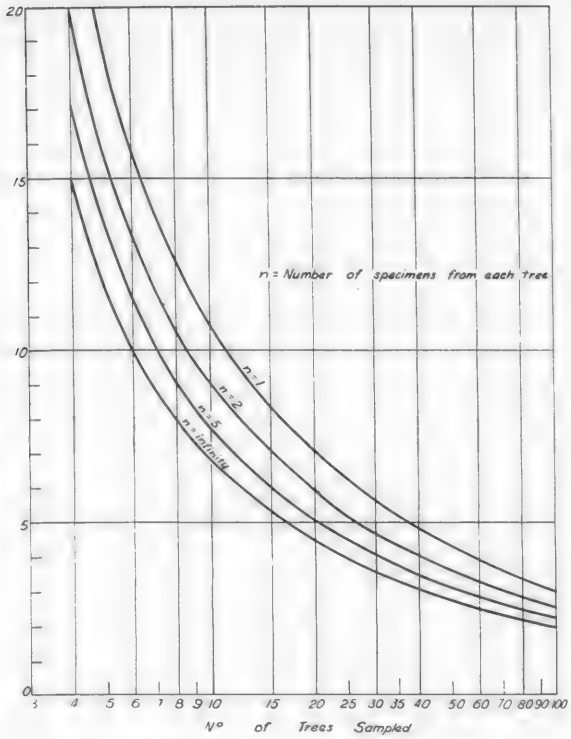

Fig. 1.—Theoretical illustration of the effect of number of trees sampled and number of specimens from each tree upon the precision with which the species mean is determined. The coefficient of variation of the population is assumed equal to 15 per cent, and the variance within trees is assumed equal to 1½ times the variance between trees.

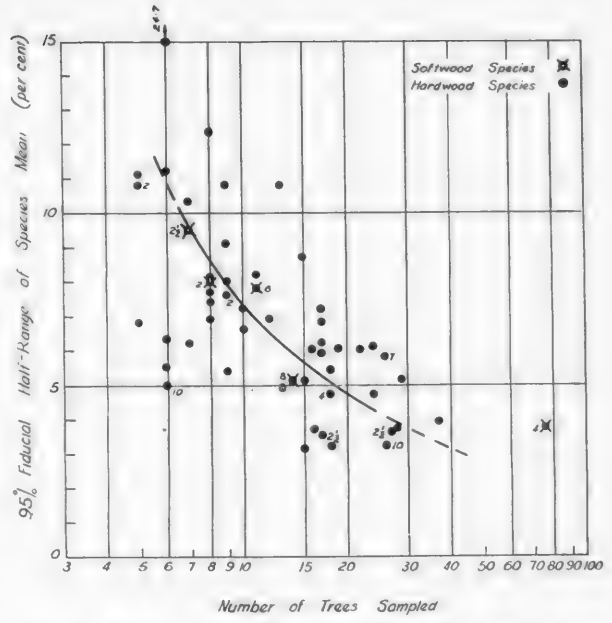

Fig. 2.—Modulus of rupture: the accuracy of the estimate of the species mean is plotted against the number of trees sampled for the results of standard tests on small, clear, green specimens of 54 Australian-grown species. Each plotted point represents one species. The average number of specimens taken from each tree is marked for species sampled with two or more specimens per tree.

the locality means and standard errors as described in the Appendix.

The following notation will be adopted:

m = number of trees selected
n_i = number of specimens taken from the ith tree
N = total number of specimens
x_i = mean of property considered for the ith tree

The correlation between specimens from the same tree makes it desirable to calculate the species mean as

$$X_u = \frac{\Sigma x_i}{m} \qquad 1)$$

that is, as the unweighted mean of tree means. This mean is appropriate if each tree is of equal importance. Sometimes tree differences are ignored and the mean is taken as

$$X_w = \frac{\Sigma n_i x_i}{N} \qquad 2)$$

that is, as the grand mean of all results. It is evident from equation 2) that the grand mean is a weighted mean of tree means. The grand mean should be regarded as the species mean only if the number of specimens taken from a tree is proportional to its importance, for example, proportional to its size, and if the tree mean x_i is correlated with tree size. However, if the number of specimens n_i is uncorrelated with the tree mean x_i, there will be no significant difference between the unweighted mean of tree means and the grand mean.

The determination of the standard error of the species mean is very much affected by the correlation between specimens from the same tree. If this correlation is ignored and the standard error is calculated from the variation of the individual values about the grand mean, the result will be spuriously low because the individual values are not all independent of each other.

Fortunately, the standard error of the unweighted mean of tree means is easily determined from the tree means themselves as

$$S_i = \sqrt{\frac{\Sigma x^2_i - (\Sigma x_i)^2/m}{m(m-1)}}, \qquad 3)$$

the same formula as would be used if the tree means x_i were the original observations. For weighted means such as the grand mean, the formula is more complicated and depends on the estimates of the variances within and between trees (see Williams 1952).

Expression 3) shows that the standard error of the species mean depends mainly on m, the number of trees, and that N, the total sample size, does not appear explicitly. An increase in the total sample size without any change in the number of trees, that is, an increase in the number of specimens from each tree only, will increase the accuracy of each x_i and hence will reduce the standard error somewhat, but not below a limit depending on the inherent variation between trees. It is therefore more satisfactory to include more trees in the sample than to sample a given number of trees more intensively.

The greater effectiveness of sampling more trees is illustrated in Fig. 1, where the 95 per cent fiducial half-range of the species mean,[3] expressed as a percentage of the mean, is plotted against number of trees sampled. Curves are drawn for several numbers of specimens from each tree. The population is assumed to have a coefficient of variation of 15 per cent, with the hypothetical variance within trees equal to 1½ times the hypothetical variance between trees. These are typical values for the coefficient of variation and the ratio of the variances, but the same general relationships shown in Fig. 1 would be obtained with other practical values.

[3] The 95 per cent fiducial half-range of the species mean is a measure of the error with which the species mean is estimated. For example, if the 95 per cent fiducial half-range is 10 per cent, then there are 95 chances out of 100 that the true mean is within ± 10 per cent of the estimated value.

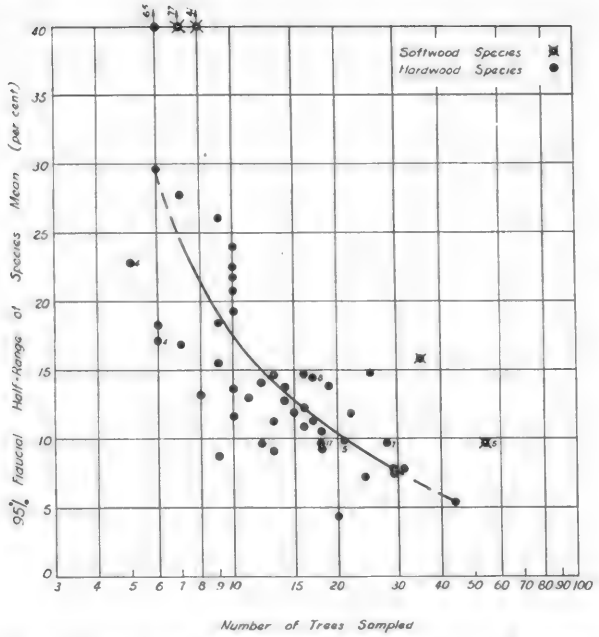

Fig. 3.—Izod value: the accuracy of the estimate of the species mean is plotted against the number of trees sampled for the results of standard tests on small, clear, green specimens of 51 Australian-grown species. Each plotted point represents one species. The average number of specimens taken from each tree is marked for species sampled with four or more specimens per tree.

Table 1.—COMPARISON OF RESULTS FROM TWO INDEPENDENT SAMPLES OF GREEN KARRI

Property	Number of trees	Total No. of specimens	Species mean (lb/sq. in.)	Standard deviation of individual results (lb/sq. in.)	Standard error of estimate of species mean (%)
Modulus of rupture	5	200	10,800	1,330	±11.0
	21	57	10,500	1,130	± 3.3
Modulus of elasticity	5	200	2.14×10^6	345	±20.0
	21	57	2.06×10^6	290	± 4.9
Maximum crushing stress	5	365	5,580	830	±13.6
	21	61	5,170	810	± 5.3
Toughness (radial)	5	376	196	32	±15.3
	21	105	201	41	± 6.0
Shear (radial)	5	42	[1]1,190	180	± 9.3
	21	21	1,210	130	± 5.3

[1]Rebated specimen: for second sample, 2 in. cube was used.

Table 2.—EFFECT OF NUMBER OF SPECIMENS PER TREE

Total number of specimens in sample	Average number of specimens per tree	Modulus of rupture: Species mean (lb/sq. in.)	Modulus of rupture: Standard deviation of individual results (lb/sq. in.)	Modulus of rupture: Standard error of estimate of species mean (%)
169	9.4	9,600	1,420	± 7
18	1	9,490	1,690	± 9
36	2	9,750	1,400	± 7

Pearson (1952) gives details of the derivation of the requisite equations.[4] It is apparent from Fig. 1 that negligible gain in accuracy is achieved by taking more than a few specimens from each tree. The smallest sample size for a given accuracy is obtained with only one specimen from each tree and this has been found satisfactory in practice.

4. Size of Sample for Standard Mechanical Testing

The sample size naturally depends on the variability of the population and the accuracy of estimate required. With increase in required accuracy, the appropriate size of the sample, and hence the cost, increased sharply. Accordingly, the accuracy of estimate required for each species should be carefully considered before planning the sample. Generally, the Australian practice is to aim at estimating the species mean within 95 per cent fiducial limits of ± 15 per cent of the mean for species relatively unimportant structurally and about ± 5 per cent of the mean for the important species. For the relatively unimportant species, about 6 trees are usually sampled and for the important species at least 15 trees, with the sampling plan so arranged that additional trees may be chosen at a later date if the first sample reveals insufficient accuracy. In many cases, only one specimen is now taken from a tree and rarely more than two specimens unless for special reasons. Information, for example, may be required about the variation within the tree, or the property may be inherently variable and the specimens small, easily obtained, and capable of being rapidly tested (such as Izod and toughness tests).

The accuracy with which the species mean has been estimated from standard tests on over 50 Australian-grown species, mostly sampled according to the above procedure, is illustrated in Fig. 2 for modulus of rupture and Fig. 3 for Izod value. All results were obtained from timber tested in the green moisture condition. Five species were softwoods and the remainder were hardwoods.

For modulus of rupture, the average number of specimens from each tree was 2.2. From only 12 species was the average number of specimens per tree 2 or more. It will be noted from Fig. 2 that the results for these 12 species do not indicate accuracies of estimate noticeably different from those obtained from samples where fewer than 2 specimens per tree were taken. Fig. 2 shows that, from a sample representing 7 trees on the average, the species mean was estimated with 95 per cent fiducial limits of ± 10 per cent, and that 18 trees were required to increase the precision of estimate to ± 5 per cent. It is also evident that, if properly selected, samples of relatively small size will enable the species mean to be estimated with sufficient accuracy.

For the Izod test, more specimens are usually taken from each tree; the average number of specimens per tree represented in Fig. 3 is about 3.2. Fig. 3 indicates that, with this sampling procedure, on the average about 12 trees were required to estimate the mean with 95 per cent fiducial limits of ± 15 per cent, and about 21 trees were needed to reduce the limits to about ± 10 per cent.

As has been stated earlier, total sample size is not an indication of the accuracy of estimate. This is illustrated in Tables 1 and 2. In Table 1 are compared some test results from two independent samples of green karri *(Eucalyptus diversicolor)*. The first sample comprised an intensive sampling of 5 trees; the second, which was selected and tested 16 years later, represented 21 trees, but the total number of specimens tested was very much less than for the first sample.

Agreement between the two sets of results is good, but it will be noted that the sample with the smaller total number of specimens, because it represents over four times the number of trees, gives a much more accurate estimate of the species mean than does the larger sample.

An illustration of the adequacy of a sample formed from only one or two specimens from each tree is provided by Table 2 in which are compared three sets of results for modulus

[4] In the expression for the 95 per cent fiducial half-range given by Pearson (1952), a term $\sqrt{(N + 1)/N}$ (on occasion $\sqrt{(m + 1)/m}$ for $n = 1$) has been wrongly included and should have been omitted. Its effect was generally negligible.

rupture of jarrah *(Eucalyptus marginata)*. All three sets were based on the same test sample of 169 specimens from 18 trees, the number of specimens from each tree ranging from 3 to 41, with 11 trees supplying more than 5 specimens per tree. The first set included all 169 results, but the second and third sets were random selections of 18 and 36 results respectively, one result being selected at random from those for each tree for the second set and two results from each tree for the third set.

The three estimates of the species mean are in close agreement, and there is no significant difference between the estimates of the standard deviation. The final column of Table 2 shows clearly that the sample comprising one specimen from each tree provided an estimate of the species mean nearly as accurate as did the original sample, which was more than nine times as large. The sample with two results from each tree compared even more favorably with the large sample.

It may be argued that the cost of sampling more trees, even if the total sample size is reduced, would be too high. However, the cost of obtaining a flitch or plank from each tree (a full log is generally unnecessary) is rarely a major part of the total cost of determining the properties of a species; the cost of preparing (including seasoning when appropriate), testing and examining the individual specimens is substantial although it is not often directly evaluated. This question is discussed by Pearson (1952), who shows that selection of one specimen from each tree is often likely to lead to the most economical as well as the most efficient size of sample. In any case, as Fig. 1 indicates, there is a very definite limit to the accuracy that may be obtained by sampling a certain number of trees, no matter what the total size of sample. If a more accurate estimate is required, more trees must be sampled.

5. Sampling Plans in Standard Specifications

(a) The British Standard: The British Standard (B.S. 373), "Methods of testing small clear specimens of timber", confines itself solely to the technical details of the carrying out of mechanical tests and makes no recommendations about the selection of specimens for test. This aspect is therefore left to the discretion of the testing authority. When small clear specimens are being tested to provide information about the batch from which they came, no detailed instructions about sampling are needed. However, when the results of the tests are likely to be used as basic information about the characteristics of the species, then it is important that the material tested shall be representative of the species, and randomly sampled.

In a recent publication, Armstrong (1955) makes recommendations for the sampling of timber for mechanical tests, and, in the absence of any standard, these recommendations might be widely adopted. Armstrong's method is to select at random five trees of the species, and to test a varying number of specimens per tree, depending on the accuracy required. His procedures for sampling and determining the error of the estimates take no account of the between-specimen correlations introduced by the sampling.

The method would be satisfactory provided the major sources of variation were represented adequately in samples of this kind; for instance, if the major variation were due to errors in testing and recording, uncorrelated from specimen to specimen. However, experience has shown that in most species there is considerable variation from tree to tree; increasing the number of specimens from each tree does not reduce the effect of this variation. Since the sampling is limited to 5 trees, the accuracy of the mean cannot be increased beyond a certain limit depending on the between-tree component of variation, as already indicated above in Section 3.

The method of determining standard errors indicated on page 2 and in Table 1 of Armstrong's paper makes no allowance for the variation between trees, and so will lead to a spuriously low estimate of the standard error. It also does not allow for the effect of sampling errors. The relationship given in his table between size of sample and fiducial range is not correct when, as is the case in practice, the mean and standard deviation are estimated from the sample.

(b) The ASTM Standard: The American Society for the Testing of Materials has issued a standard (D 143–52) for testing small clear specimens of timber. This standard is mainly concerned with mechanical tests and the techniques for carrying them out, but it also deals briefly with method of selection of material. It states:

> "For each species to be tested, at least five trees representative of the species shall be selected."

Later, under the heading "Selection for Important Species", it gives the additional requirement:

> "For important species of wide geographical distribution, test material shall be selected from two or more localities or sites."

These provisions are very general, and their interpretation is left to the testing authority. If the data are to be used to estimate means and standard errors, the provisions need to be interpreted as recommendations to random sampling. However, the discussion in Section 3 shows that often more than five trees will be desirable.

There are also provisions for the selection of one bolt from each tree, and additional bolts from some trees, to provide information on variation of properties with height in tree. Further on, the standard gives methods of sawing up the bolt to provide sticks from each of which a specimen for each standard test is taken. These clauses give an objective method of selecting sticks but provide for an intensive sampling of each tree. The only advantage of such intensive sampling is that it enables the variation of properties within the tree from pith to bark and butt to top to be determined.

6. Variation of Properties within the Tree

Knowledge of the variation of properties within the tree, from pith to bark or from butt to top, can only be obtained by taking a number of specimens from each tree. Such knowledge is of considerable interest, particularly in relation to some plantation-grown species. However, it is not often of direct commercial importance because timber from different parts of the tree is rarely sorted and sold separately, and it is sufficient to know the mean value and total variability for the relevant properties of the material marketed. Accordingly, it is unnecessary and costly to determine variability within the tree as a routine procedure in species testing; when it is required, it can be obtained more economically from an investigation designed for that purpose.

It should be noted that determination of the variability within the tree is not necessary for estimating the total variability of the species. The latter can be estimated even if only one specimen is taken from each tree providing it is selected at random from the tree. In fact, a sample comprising one random specimen per tree estimates not only the mean but also the standard deviation of the species more accurately than a sample of the same total size but representing fewer trees.

Willingness to dispense with the determination of the variability within the tree, which is largely of academic interest, and to increase the number of trees represented in the sample, enables the total sample size to be

greatly reduced and still produce estimates of the species means and standard deviations to the required degree of accuracy. Reduction in sample size not only leads to a reduction in the cost of species testing but also to a considerable increase in the number of species that can be tested in a given time. The Division of Forest Products, CSIRO, adopted the sampling procedure advocated in this paper in mid-1949, and since then, with the same testing facilities, testing has been carried out on samples representing 771 trees from 80 species, a five-fold increase over the previous rate of testing of species.

7. Conclusions

From experience with the testing of Australian species and a survey of testing standards, the following conclusions are drawn.

1. More attention should be given to specifying satisfactory sampling methods; in particular, specifying that the representative sample shall be obtained by random selection. As the provision of random selection is liable to wide differences of interpretation, any such provision in a standard would need to specify precisely how the random selection is to be carried out.

2. Sampling methods should allow for adequate sampling of locality and tree variation, and the intensity of sampling at each stage (localities, trees) should be indicated in relation to the accuracy of estimate desired.

3. The present method of cutting a large number of sticks from each bolt should be replaced by a more flexible but equally precisely defined method which will enable as few as one or two sticks to be taken at random from each tree. This will lead to relatively small sample sizes with a consequent increase in the rate at which species can be tested.

4. The correct method of calculating estimates of species properties, and their standard errors, should be clearly set out, as misconceptions appear to exist about the effect of variation within and between trees.

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Appendix—Calculation of the Species Mean and its Standard Error for a Stratified Sample

Where the geographical range has been subdivided into a number of homogeneous localities, it is highly desirable that each locality should be sampled because the standard error of the species mean may then be based on the variation within localities. If, however, it has been necessary for any reason to select only a sample of localities, the standard error will have to be based on the variation between localities. Selecting only a sample of localities has the double disadvantage that the sampling error is increased by the inclusion of variation between localities and that, unless the localities are numerous and the sample is large, this locality variation will be poorly estimated.

Assume first that every locality has been sampled so that the standard error will be based on the variation within localities. From the means and standard errors for each locality, we can build up the mean and standard error of the species. It will be noted that the general arguments and conclusions of Section 3 are applicable. We shall use the following notation:

k = total number of localities
m_i = number of trees sampled in ith locality
n_{ij} = number of specimens from the jth tree, ith locality
n_i = total number of specimens, ith locality
x_{ij} = mean of property considered for the jth tree, ith locality

The locality means will be determined from the tree means x_{ij}. The ith locality mean is usually taken as the unweighted mean of tree means X_{ui}, where

$$X_{ui} = \sum_j v_{ij}/m_i \qquad A1)$$

Sometimes tree differences are ignored and the mean is taken as

$$X_{gi} = \sum_j n_{ij}x_{ij}/n_i \qquad A2)$$

that is, as the grand mean of all results.

The standard error of the unweighted mean of tree means is easily determined from the tree means themselves as

$$s_i = \sqrt{\frac{\sum_j x^2_{ij} - (\sum_j x_{ij})^2/m_i}{m_i(m_i - 1)}}, \qquad A3)$$

the same formula as would be used if the tree means x_{ij} were the original observations. For weighted means such as the grand mean, the formula is more complicated and depends on the estimates of the variances within and between trees (see Williams, 1952).

Now if the weight for the ith locality, representing its importance for the species, is denoted by w_i, then the estimated species mean is given by

$$X_w = \sum_i w_i X_{ui}/\sum_i w_i \qquad A4)$$

and its standard error by

$$s_w = \sqrt{\sum_i w_i^2 s_i^2/\sum_i w_i} \qquad A5)$$

Alternatively, the standard error s_w may be estimated from the pooled mean square of the deviations of the tree means from their locality means. This procedure is particularly applicable when the number of trees from each locality is small. The standard error of the species mean is then calculated as

$$s_w = \frac{s_t}{\sum w_i}\sqrt{\sum \frac{w^2_i}{m_i}}, \qquad A6)$$

where s^2_t is the estimate of the sampling variance of the tree means about the locality means and is given by

$$s^2_t = \frac{\sum_i \left[\sum_j x^2_{ij} - (\sum_j x_{ij})^2/m_i\right]}{\sum_i m_i - k} \qquad A7)$$

If only k_s ($<k$) localities are sampled, the species mean is calculated from equation (A4) with $i = 1, 2, \ldots k_s$. Its standard error is dependent not only on the variance of the tree means within localities, s^2_t, but also on the variance of the locality means about the species mean. The standard error is calculated as

$$s_s = \frac{1}{\sum_i w_i} \cdot \sqrt{\frac{k - k_s}{k_s - 1} \cdot \frac{k_s}{k} \cdot \sum_i w^2_i (X_{ui} - X_w)^2 + \frac{k_s}{k} \cdot s^2_t \cdot \sum_i w^2_i/m_i} \qquad A8)$$

where the summations are taken over the k_s localities, and the denominator of s^2_t (equation A7) becomes $\sum_i m_i - k_s$.

When all localities are sampled, that is, $k_s = k$, equation A8) reduces to equation A6).

Around the World in Forest Products Research and Development

Plywood Commodity Report Published in Unasylva

A Commodity Report on Plywood has been published in V. 12, No. 2, of UNASYLVA, a FAO publication. It contains a review of significant developments of the period 1946 to 1957, but main emphasis is laid on developments between 1955 and 1957.

The article states that world production of plywood increased during the period 1946–1957 by almost four times. The largest volume increase took place in the U.S.A., with the largest relative increase occurring in Asia (chiefly Japan). A relatively rapid rate of growth of production occurred in the U.S.S.R. since the war to 1952, when the course of expansion became calmer and followed a more regular and modest trend of annual growth.

The volume of world trade in plywood in 1946 to 1947 was some 11 per cent of total world production. Since 1951 this has become stabilized at around 9 per cent. In 1946, Finland and North America represented about 76 per cent (41 and 35 per cent respectively) of total world exports of plywood. Since then, the share of North America has fallen to about 9 per cent in 1956 and 1957, and Finland's share has fallen to 25 and 23 per cent respectively in 1956 and 1957.

Japan has increased its exports most rapidly, both as regards a share in the world market and actual volume. From nothing in 1946, Japanese plywood exports in 1956 amounted to 30 per cent, and in 1957 to 27 per cent of total world exports. They are the world's number one plywood exporter.

The United Kingdom was in 1946 the largest plywood importer, with 65 per cent of total imports. This has since declined to 31 per cent in 1956 and 35 per cent in 1957. The United States, on the other hand, a small importer in 1946 with only 4 per cent total imports, has gradually risen to number one importer with 46 per cent in 1956 and 40 per cent in 1957.

The growing importance of Japan as an exporter, and that of the United States as an importer, are in fact interdependent, since the largest share of Japan's exports has so far been destined to the United States.

While sawnwood export prices by and large maintained their 1955 position in 1956 and 1957, plywood prices tended to weaken. By contrast, the cost of labor and transport has steadily increased. A consequence of the weakness in plywood export prices has been a shrinking offer of peeler logs to the industry.

Scanning World-Wide Forest Products Publications

Japan

Chemical Studies on Bark. IV. Comparison of Lignin between Bark of Gymnosperm Trees and that of Dicotyledonous Trees. Katsumi Hata and Murao Sogo. *Journal of the Japan Wood Research Society,* V. 4, No. 3. (In English)

Inner bark, outer bark, and sapwood of gymnosperm trees (4 species) and dicotyledonous tree (4 species) were extracted with alcohol-benzene (1:1) and hot water. These samples were subjected to the Mäule test. Fibrous tissues in inner and outer barks of dicotyledonous trees produced a purple-red color by the treatment of the Mäule test, whereas the tissues in the bark of gymnosperm trees produced only a weak, yellowish-brown color.

These samples were oxidized with alkaline nitrobenzene, and then the oxidation products were examined by means of paper chromatography to determine the existence of syringic acid, protocatechualdehyde, vanillic acid, 5-formyl vanillic acid, p-hydroxybenzaldehyde, syringaldehyde, vanillin, acetoguaiacone, and p-hydroxyazobenzene. It was indicated that inner bark and outer bark lignins of gymnosperm trees had guaiacyl type, p-hydroxyphenyl type, and 3,4-dihydroxyphenyl type building stones, and had a very small amount of syringyl type building stone, or might not have this type building stone, whereas inner bark and outer bark lignins of dicotyledonous trees had syringyl type, guaiacyl type, p-hydroxyphenyl type, and 3,4-dihydroxyphenyl type building stones.

Australia

Withdrawal Resistance of Grooved Nails. J. J. Mack. *C.S.I.R.O. Forest Products Newsletter,* No. 242.

Nails with specially rolled annular or spiral grooves are now being made in Melbourne, and tests are being carried out to investigate their efficiency in withdrawal resistance. Although these tests are incomplete, some information is available that may be of interest to nail users.

Four types of nails are being examined. Their withdrawal resistance is being compared with the withdrawal resistance of plain shank nails of the same gage and composition of wire.

1) 2 in./13 S.W.G. Monel metal nail with annular groove;
2) 1½ in./ 9 S.W.G. low carbon steel nail with helical groove;
3) 2¼ in./8½ S.W.G. low carbon steel nail with helical groove;
4) 2¼ in./5 S.W.G. aluminum roofing nail with helical groove.

Some nails are being driven into green and others into dry radiata pine. Some are being pulled immediately and others at various periods after driving. For the delayed tests on green timber, the wood is being allowed to dry after the nails are driven.

For use in radiata pine it is clear from these results that grooved nails of the types tested are definitely superior in withdrawal resistance to plain nails for all normal conditions of use. Immediate withdrawal resistance in both green and dry timber, and also that after a delay period, was greater than that of plain nails. An interesting feature is that their withdrawal resistance actually increased a short time after driving, while that of plain nails fell quite considerably. This was particularly noticeable with green pine, when the withdrawal resistance of the rolled nails after 4 months was up to seven times that of the plain nails.

The "popping" of nails used for fixing hardboard is being investigated. Results so far indicate that the drying of green wood or the fluctuations of the moisture content of dry timber into which the nails are driven can cause a gradual outwards movement of the nail. Annularly grooved nails tested in comparisons with ordinary plain hardboard nails were not affected as much as the latter. It is therefore suggested that timber, or at least that portion of wood penetrated by the nail, should be as dry as natural conditions allow before hardboard wall surfacing is fixed. It is indicated also that some benefit is gained by using grooved nails.

Abstracts From Current World Literature

Pathology

Engelhardt, N. T. Pathological deterioration of looper-killed western hemlock on southern Vancouver Island. *For. Sci.* 3, no. 2: 125–36 (June, 1957).

The most important causes of deterioration of tree stands killed by an attack of the western hemlock looper *(Lambdina fiscellaria lugubrosa)* in 1944–46 were found to be wood-rotting fungi, insects causing only limited and secondary damage. In the first two years, decay did not penetrate radially more than one inch on the average, but thereafter the radial penetration increased rapidly, and by the end of the fifth year the sawlog volume was reduced below the point of economical recovery. Insect holes appeared to be an important portal of entry for decay fungi, particularly in the early stages. *Fomes pinicola*, a fungus attacking both sapwood and heartwood, was found to cause the greatest damage. Amabilis fir deteriorated as rapidly as hemlock; Sitka spruce was somewhat more and Douglas-fir considerably more resistant. [Bul. Pap. Chem. V. 28, No. 4]

Foreign Woods

Mora (Mora excelsa). *Woodworking Industry*, Vol. 13 No. 5, May 1956, p. 273.

Although it is one of the most important timbers of British Guiana, Mora is not very well known on the world's markets.

It is a very dense wood suitable for structural purposes with a decorative appearance. The average weight is 60–68 lb. cu. ft. when seasoned and, as is to be expected, it is rather difficult to work. The texture is open and somewhat uneven. Its resistance to fungal attack is high and it is said to be fire-proof. It can be drilled and mortised cleanly, and its screw- and nail-holding properties are very good. [F. D. C. Tech. Bul. V. 7, No. 38]

Wood Structure

Carlsson, Carl Axel, and Lagergren, Stig. Studies on the interfibre bonds of wood. Part 2: Microscopic examination of the zone of failure. *Svensk Papperstidn.* 60, no. 18: 664–70 (Sept. 30, 1957). [In English; Swedish and German summaries] *cf.* abstract no. 2158.

The optical properties of the cell wall of spruce- and birchwood are discussed. The microscopical and tensile-testing techniques used in studying the zones of failure in wood subjected to heat, swelling, or delignification are described. The results obtained in the first part of this study *(cf.* abstract no. 2158) are confirmed by the photomicrographs. [Bul. Pap. Chem. V. 28, No. 4]

Hardboard

Anderson, Arthur B., and Helge, Kjell. The utilization of unbarked residues in hardboard. *Norsk Skogind.* 11, no. 9: 327–30 (Sept., 1957). [In English; Norwegian summary] *cf.* B.I.P.C. 27: 1367–8.

The properties of hardboards made solely from unbarked slabwood and thinnings were studied. Pine slabs, spruce slabs, pine thinnings, and spruce thinnings containing 39.2, 24.5, 8.2, and 15.3% bark, respectively (on an ovendry basis), were processed separately in an Asplund laboratory defibrator, with and without heat treatment and/or paraffin-alum sizing. Preliminary data indicated that all four raw materials can be used for producing acceptable standard hardboards. Moreover, pine slabwood containing 39% bark produced a board having good dimensional stability even without added sizing agents and without heat treatment. Spruce bark did not exert such a sizing effect, probably because of the different nature and amount of extractive components. [Bul. Pap. Chem. V. 28, No. 4]

Barkers

Eaton, John C. New slab-to-chips system makes debut. *Pulp & Paper* 31, no. [illegible] 144–6 (May, 1957).

Advantages claimed for the new Eaton log debarker include low cost, a simple and rugged construction, simple operation with only three controls, and no special tool requirements for repair. The new barker has made possible the installation of novel co-operative slab-to-chip concentration yards requiring only three people for operation. [Bul. Pap. Chem. V. 28, No. 4]

Sorption

Kollmann, Franz, and Schneider, Adolf. Measurements of sorption on excelsior slabs. *Holz Roh- u.* Werkstoff 15, no. [illegible] 321–4 (Aug., 1957). [In German; English summary]

Sorption isotherms of gypsum- and magnesite-bonded excelsior slabs were obtained by a new method involving direct manometric measurements of water-vapor pressure at equilibrium over the samples in an air-free chamber. The measuring instrument is based on the principle of the Dubrovin manometer and has a precision of $\pm 4 \cdot 10^{-2}$ mm. For dry-weight determinations, the samples were subjected to a high vacuum (water-vapor equilibrium pressure below 4×10^{-2} mm.) at 20° C., then dried at 105° to constant weight. The weight loss was 15.6 and 15.1% for gypsum-bonded and 4.5% for magnesite-bonded slabs. In gypsum slabs, this is attributed to the loss of 75% of water crystallization from the binder; in the magnesite slabs, the weight loss also involves the binder, but the chemical reactions causing it are not known. [Bul. Pap. Chem. V. 28, No. 4]

Stamm, Alfred J. Adsorption in swelling versus non-swelling systems. II. Free energy change per unit area of effective molecular contact. *Tappi* 40, no. 9: 765–70 (Sept., 1957).

In the previous paper (*cf.* abstract no. 1368), the B.E.T. equation was applied to adsorption-isotherm data for swelling gels and true solutions to obtain the effective molecular contact area of the condensed adsorbate with the adsorbent. This makes possible the calculation of the free energy of adsorption per unit of effective molecular contact area. The values for the adsorption of water vapor on various swelling solids, including wood, cellulose, isolated lignin, starches, and proteins, are practically independent of the adsorbent. The same is true for water solutions having appreciable heats of solution. The free energy change per unit of effective molecular contact area between various adsorbents polar vapors (e.g., alcohols) and cellulose, cellulose acetate, or wool increases linearly with the reciprocal of the molecular volume of the condensed vapor. A similar relationship has been shown by earlier investigators to hold for adsorption on nonswelling powders. These free-energy values are equivalent to the work of adhesion. It has been estimated from the values for work of adhesion that the free surface energy of formation of a gel-vaccum interface for cellulose, cellulose acetate, and wool is between 45 and 70 ergs/sq. cm. [Bul. Pap. Chem. V. 28, No. 3]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Counzil at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

Laminating Preservative-Treated Scotch Pine

M. L. Selbo, U.S. Forest Products ab., and Ole Grønvold, Norsk Tre-knisk Institutt. Condensed from ıe September, 1956, issue of Norsk kogindustri. The senior author was Fulbright research scholar at the orwegian Institute of Wood Work-ıg and Wood Technology during ıe academic year 1955-56.

Materials and Procedures

SCOTCH PINE *(Pinus silvestris)*, widely used for boatbuilding and similar applications in Norway, was used for these investigations. The preservatives used were Celcure (acid copper chromate), Boliden salts (Chromated zinc arsenate), and creosote.

The treating was done at commercial treating plants and the average retention was 0.72 pound per cubic foot for the Celcure, 0.37 pound per cubic foot for the Boliden salts, and 5.69 pounds per cubic foot for the creosote. Average retention for the creosoted material was slightly lower than that specified by American Wood Preservers Assoc. Standards because the Scotch pine used contained a large percentage of heartwood, which is difficult to treat. However, the sapwood appeared to be adequately treated.

The salt-treated materials were kiln dried to about 10 per cent moisture content. They were surfaced smoothly and to uniform thickness shortly before gluing. The creosoted material was stickered under a roof for several weeks before it was surfaced and glued.

Four glues were used: an acid-catalyzed phenol, 2 straight resorcinols (one each manufactured in Norway and Sweden) and a phenol-resorcinol manufactured in the United States.

Three different curing temperatures, 59°, 77°, and 95° F. (15°, 25°, and 35° C). were used. Since Scotch pine is lower in density than Douglas-fir, it was thought that temperatures somewhat lower than those required for the latter would be satisfactory. The glue spread was about 60 pounds of wet glue per 1,000 square feet of joint ırea, the closed assembly time was 30 - 40 minutes, and the gluing pressure as about 175 pounds per square inch. Maximum and minimum assembly ines were not investigated since it was ınsidered more important first to termine if adequate glue bonds could obtained when reasonably normal sembly periods were used.

After the assemblies were spread (each consisting of 6 laminations, ¾ by 6 by 24 inches), they were pressed in retaining clamps. The curing was done in a chamber with controlled temperature and humidity. The humidity was maintained at a level that prevented appreciable change in the moisture content of the assemblies during the curing period of about 16 hours. The assemblies were then unclamped and stored at a temperature slightly below 59° F. (15° C.).

Testing

Two-inch sections were cut from 1 end of each beam and discarded. Two stair-step type shear block specimens were cut from the next 3¼ inches of the beam and subjected to the block shear test in accordance with ASTM D 905–49. Another 3-inch section was cut from each beam for delamination tests, which were carried out in accordance with ASTM D 1101–53. The results of the delamination test are shown in Table 1 and those of the block shear tests in Table 2. The results of the delamination test were statistically anlyzed.

Discussion of Results

Results in Table 1 show that creosote interfered most with development of adequate glue bonds, particularly at the lower curing temperatures. In general, there was no significant difference in the delamination values for the salt treatments (Boliden salts and Celcure) and the untreated material. With the

Table 1.—Results of delamination tests on laminated Scotch pine glued from treated and untreated materials and cured at three different temperatures

Preservative	Amount of delamination with various glues and curing temperatures: Acid phenol %	Resorcinol I %	Resorcinol II %	Phenol resorcinol %	Average %
		59°F. (15°C.)			
Boliden salts	0.2	15.5	2.0	4.0	5.4
Untreated	.5	9.7	.2	.3	2.7
Celcure	.1	8.3	1.4	4.6	3.6
Creosote	11.2	62.9	8.2	21.0	25.8
Average	3.0	24.1	3.0	7.5	
		77°F. (25°C.)			
Boliden salts	.0	6.5	.6	2.2	2.3
Untreated	4.6	0.9	.9	.4	1.7
Celcure	.3	1.2	2.1	.0	.9
Creosote	9.6	18.6	5.5	7.2	10.2
Average	3.6	6.8	2.3	2.4	
		95°F. (35°C.)			
Boliden salts	.2	.6	.4	.2	.4
Untreated	.1	.2	.4	.3	.3
Celcure	6.3	.5	4.7	1.4	3.2
Creosote	6.3	5.2	4.0	1.8	4.3
Average	3.2	1.6	2.4	.9	
Total Average	3.3	10.8	2.6	3.6	

Table 2.—Results of block shear tests on laminated sections of Scotch pine (Pinus silvestris) treated with 3 different preservatives and glued with 4 different glues[1]

Preservative	Shear strength and percentage of wood failure with various preservatives, glues, and curing temperatures: Acid-Phenol Psi	%	Resorcinol I Psi	%	Resorcinol II Psi	%	Phenol-Resorcinol Psi	%	Average Psi	%
			59°F. (15°C.)							
Boliden salts	1235	95	982	45	1187	65	1081	80	1121	71
Untreated	1140	95	931	30	1015	95	924	100	1001	80
Celcure	1253	95	993	65	1191	90	946	75	1096	81
Creosote	1246	85	832	25	971	65	1308	70	1089	61
Average	1217	93	935	41	1092	79	1063	81		
			77°F. (25°C.)							
Boliden salts	1246	90	1063	75	1162	85	1059	85	1132	84
Untreated	1037	95	1055	80	1121	90	1264	80	1118	86
Celcure	990	90	1250	75	1015	85	1158	90	1103	85
Creosote	1360	90	1136	65	1286	80	1356	75	1283	78
Average	1158	91	1125	74	1147	85	1209	83		
			95°F. (35°C.)							
Boliden salts	997	90	1063	95	1103	90	1096	95	1063	93
Untreated	1059	80	1162	90	1088	95	1107	85	1103	88
Celcure	1154	90	1076	90	1052	90	1136	95	1103	91
Creosote	1279	95	1180	80	1261	80	1367	95	1272	88
Average	1121	89	1121	89	1125	89	1176	93		

[1]Each value in this table is the average of values for 10 shear tests.

creosoted material, only the 95° F. curing temperature produced what appeared to be satisfactory results. The salt-treated and untreated material in general glued satisfactorily at all temperatures, except with resorcinol I at the 59° cure.

In glue joint performance, the acid phenol showed little difference for the three curing temperatures used, except possibly with the creosoted material where the delamination was lowest at the highest curing temperature. Resorcinol I showed the poorest results of the 4 glues used at the 59° F. curing temperature. But the results improved as the temperature increased, and at the 95° F. cure the delamination was less than 1 per cent for all the materials glued with this glue, except the creosote-treated. Resorcinol II did not show a great deal of difference in the delamination values for the three temperatures with untreated and salt-treated material except for creosote-treated material, where the delamination decreased as the curing temperature increased. The phenol-resorcinol type of glue showed decided decrease in delamination on creosote-treated material as the curing temperature increased. For the untreated and salt-treated materials, the differences in the delamination for the different curing temperatures were slight, although the trend seemed to be improved results with higher curing temperatures.

The results of the block shear tests in Table 2 show that some of the glues are definitely more affected by the curing temperature than are others. Resorcinol I showed somewhat reduced shear strength and definitely lower wood failure values at the 59° curing temperatures compared to results at higher temperatures. At the 95° cure, however, there was no significant difference in the shear values of all 4 glues used.

Statistical analysis showed the effect (as obtained by analysis of variance) of glue, preservative, and curing temperature on delamination. There was a significant difference in the performance of the glues when the averages for all curing temperatures and preservatives were considered. There was also a significant difference in the performance of creosote-treated materials and materials treated with the other preservatives. The creosote-treated material produced the lowest glue-bond quality. This is based on averages for all three curing temperatures and all glues used. The analysis also showed a significant difference in the results obtained at the three curing temperatures when averages for all glues and treatments were considered.

Conclusions

The results of this study, interpreted in the light of previous work on gluing of treated wood, warrants the following conclusions:

1) Scotch pine treated with Celcure and Boliden salts, as well as untreated Scotch pine, can be glued satisfactorily with resorcinol and phenol-resorcinol glues when cured at a temperature of 77° F. (25° C.) or more. It is possible that in production some increase in curing temperature may be needed for consistently adequate results.

2) There are definite indications that creosote-treated Scotch pine can be satisfactorily laminated with the same glues when a curing temperature of 95° F. is used. It is possible that in production an even higher curing temperature may be needed to give consistently adequate results.

3) Satisfactory initial results were also obtained with an acid-catalyzed phenol on treated and untreated Scotch pine. Because of the varied experiences reported on the durability of acid-catalyzed phenols, this type of glue is not recommended for uses requiring long-term durability.

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Cut Stock

Paul Watts, Paul Watts, Inc., Cincinnati, Ohio. Presented at the Inland Empire Section Meeting, Sept. 27, 1957, at Omak, Wash.

For the purpose of this paper cut stock will be defined as wood parts that have been cut from lumber which may or may not be further machined. Manufacturers are rarely interested in using boards. They think in terms of an end product. The lumber user pays freight on waste, accepts a variable yield factor, uncertain inventory, and tries to work on an average cost rather than a specific cost. These factors favor the use of cut stock.

Wood parts produced at the source of lumber production can be made of marginal grades, edgings, slabs, and culls, and can be dried properly for use, on the first round. With several end use requirements, from millwork to box shook, the producer can cut to best utilization for both clean and sound grade requirements.

A recent survey taken by the National Association of Furniture Manufacturers of their membership, revealed that hardwood dimension (the southern equivalent of western cut stock) was used because it increased plant capacity, lowered cost of wood parts, reduced necessary capital investment, and assured definite raw material cost.

This would seem to indicate that a market for cut stock exists. Freight rates have increased and more increases are inevitable. This not only has an impact on lumber costs but makes the savings greater on waste percentage-wise. Present trends are toward fabricating plants that can distribute their end product within a 300-mile radius and thereby hold down the delivered price of their end product. Geared to the mass assembly of product, these firms do not care if they use wood. They are interested in the best designed parts possible for their product.

Many cut stock plants have failed largely because they were not completely engineered, planned and integrated along program lines. For any success a cut stock operation must be equipped to use most, if not all, of the species cut and some or all of the grades as basic surveys would indicate were best for that particular operation.

A planned sales program should be established to insure end use of all the species and combinations of grades so that waste is at a minimum and utilization is more nearly complete. The sales department must generate three or four basic outlets for primary species and grade developments. Efficient methods, equipment and excellent quality control should be used.

Today sound and paint grades are in demand because of the advent of print and full cover finishes. Outlets should be diligently developed for each. Only the best methods and equipment will even allow a firm to compete. The basic economic advantages that can be offered to the user of cut stock is less freight and waste, a known cost on a set of parts, accurate inventory control and unit cost.

A long range profitable operation would certainly go beyond the plan... mill type of business but does not need to extend to shaping, boring, and mould sanding. An intelligent study of species, grades and the available investment dollar would best give the answer at what level to begin a plant and program.

Fiber Supply

E. L. Lamb, Vice President in charge of Planning and Development, Minnesota & Ontario Paper Co., International Falls, Minn. Presented at the FPRS Upper Mississippi Valley Meeting, Aug. 15, 1958, at International Falls.

The principal industries in this country that depend primarily on wood as a source of fiber are pulp and paper, structural insulating board and hardboard, and derivative cellulose. By way of perspective, for every 100 units of wood consumed to produce lumber, 25 units are consumed for pulpwood, 1½ units for fiber board and hardboard, and 2 units for chemical cellulose. A number of studies recently carried out estimate that the rate of demand for fiber board and chemical cellulose will more than double in the next 20 years.

Potential mill sites exist in the Southern part of the United States for both paper and structural board plants. About 60 per cent of the Southern forests are hardwoods. Exploitation of these stands probably depends in part on further advances in pulping technology. It seems reasonable to expect that further expansion in the number of species utilized will contribute to supplying the anticipated increase in demand in the next quarter century.

The Standford Analysis of future wood requirements undertaken under the auspices of the Weyerhaeuser Timber Co. considers that proportionately one of the large sources of increased wood for pulp will be mill waste. Currently it accounts for about 6 per cent of the pulpwood consumed. In the next quarter century, the analysis estimates that it will increase about six-fold while the total requirements for pulpwood will increase somewhat less than twice.

Normally about 1/3 of the paper and paper board produced in this country is recovered for reuse. The bulk of waste paper recovered is used for paper board where quality requirements are not too critical. Other uses are for the production of white pulp for printing papers, and for structural insulating boards. Reuse of waste paper has varied from 30 per cent of the raw material used in 1940 to 36½ per cent in 1944. Waste paper is a potential source of fiber to replace the drain on new wood if the cost of producing pulp from wood becomes high enough to make the use of waste paper economical.

In the main, recovery of pulp from agricultural residues has not been successful in the United States, although there are some exceptions. A number of factors impede the extensive use of these residues in paper making. Among these are the need to operate a pulp mill practically continuously because of the high capital cost and the problem of storing enough of an annual crop to run for a year. Another serious problem is the removal of dirt and other foreign materials.

In recent years, some of the forests in this country have been placed under intensive methods of forest management. A number of foresters consider it practical in some areas where pulpwood is grown to increase the production per acre per year on a sustained yield basis to something in the nature of two to four times that obtainable from unmanaged growth. It seems almost certain that the potential available from improved forest management will be one of the largest factors involved in insuring adequate supplies of wood as the demand for it increases more or less linearly with the expanding population.

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Wood Research No. 34, What Wood Can You Use in Particle Board? R. C. Cranch. Contains a tabular listing of wood species that have been found suitable for particle board manufacture as well as other species used in the experimental manufacture of boards. Available without charge from the Timber Engineering Co., 1319 18th Street, N. W., Washington 6, D. C.

Determination of Dihydroquercetin in Douglas Fir and Western Larch Wood. G. M. Barton and J. A. F. Gardner. Discusses development of a rapid colorimetric method for routine determination of dihydroquercetin in species mentioned. Reprint from *Analytical Chemistry,* Feb. 1958. Available from the Vancouver Laboratory, Forest Products Laboratories of Canada, B. C., Canada.

Controlling Your Sawmill Production. G. W. Andrews. Reviews some aspects of production control in the sawmilling industry. Reprint from Canada *Lumberman,* May 1958. Available from the Ottawa Laboratory, Forest Products Laboratories of Canada, Ontario, Can.

The Plywood Industry of Japan. J. H. Jenkins. Observations of a Canadian on the Japanese Plywood Industry. Reprint from *Canadian Woodworker,* April, 1958. Available from the Ottawa Laboratory, Forest Products Laboratories of Canada, Ontario, Can.

Recommended Revision of Commercial Standard CS176–51, Prefinished Wall Panels. Released by Commodity Standards Division, U. S. Dept. of Commerce. The revised standard establishes criteria of physical requirements for base material and the finish coating. Limited copies of the revision TS-5396 are available on request from the Commodity Standards Division, U. S. Dept. of Commerce, Washington 25, D. C.

Teco Du-Al-Clip Framing Anchors. The booklet shows economical applications and design data for these clips. Also featured are tables of safe working values and maximum joist spans. Available free of charge from Timber Engineering Co., 1319 18th Street, N. W., Washington 6, D. C.

Seventh Industrial Forestry Seminar, Oct. 7–18, 1957. Contains a complete account of discussion during the seminar that was held at Crossett, Arkansas. Available for $6.00 from the Yale School of Forestry, New Haven, Conn.

The following publications are available free of charge from the U. S. Forest Products Laboratory, North Walnut Street, Madison, Wis.

List of Publications on Wood Finishing Subjects. Report No. 454

List of Publications on Wood Preservation. Report No. 704

List of Publications on The Seasoning of Wood. Report No. 446

List of Publications on Logging, Milling, and Utilization of Timber Products. Report No. 790

Partial List of Government Publications of Interest to Architects, Builders, Engineers, and Retail Lumbermen. Report No. 1081

Studies of the Methodology of Soil-Block Testing. Catherine G. Duncan. Describes tests comparing the effects of different kinds of preservatives on various species of wood. Test variations that occur because of differences among and within wood species are also summarized. Report No. 2144, 126 pp.

Evaluation of Nine Styles of Fiberboard Boxes with More than Four Sides. T. B. Heebink. This study summarizes the results of drop tests on boxes of unorthodox shapes. Report No. 2110.

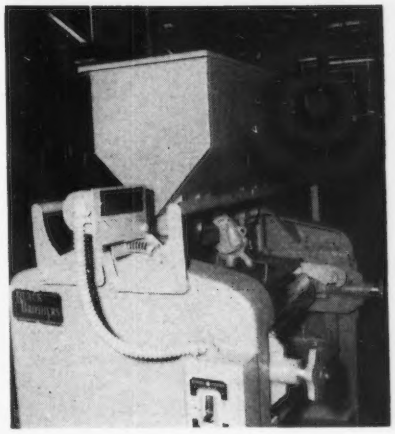
Performance of Structural Pole Frames Under Test Load. D. V. Doyle. Gives the results of tests of full-sized structural pole frames to determine their strength and rigidity under simulated wind and snow loads. Report No. 2111.

Bin Pallets for Agricultural Products. T. B. Heebink. This report outlines recommendations for building bin pallets for the storage and handling of such commodities as apples, potatoes, and peaches. Report No. 2115.

Pulping and Papermaking Experiments on Colombian Woods. G. H. Chidester and E. R. Schafer. Summarizes research on 31 species of wood from Colombia, South America. The hardwood pulps of these species were blended successfully and made into different types of paper. Report No. 2117.

Transportation and Handling of Whole Trees. E. W. Fobes. Describes savings that can be gained from the logging of whole trees. Report No. 1637–57.

NEW PRODUCTS—LITERATURE

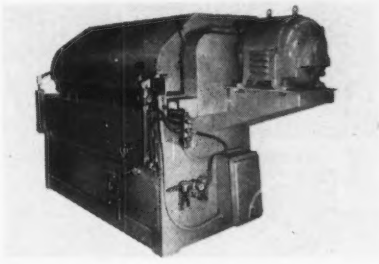


V-Shaped Glue Tank

A new "V" shaped glue supply tank is being manufactured by the Black Bros. Co., Inc. The tank can be added to any existing #22-D glue spreader or can be specified on a new machine at time of purchase.

The tank mounts on the "T" iron that extends across the top of the machine. Sizes start at 15 gallons and depend on the size of the spreader. The usual construction material is sheet steel, but either a galvanized iron or a stainless steel tank can be supplied at extra cost. Water jacketed tanks can also be supplied.

More information is available from the Black Bros. Co., Inc., Mendota, Ill.

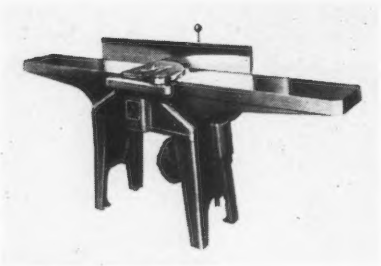


Heavy-Duty Sanders

Timesaver "Speedbelt" Sanders are now available in heavy-duty, high-speed models called "Ram Type", the firm announced recently. Changes include automatic jet air abrasive belt tracking.

The machines are built in 24 inch to 54 inch belt widths and can be equipped with the Timesaver Dual Action Polishing Platen for a 2-in-1 cutting operation on wood.

Prices on the heavy duty "Ram Type" construction models are higher than standard models SPL and TOP. More information is available from Timesaver Sanders, P. O. Box 7446, Robbinsdale Station, Minneapolis 22, Minn.



Twelve-Inch Jointer

A newly designed, lower priced 12-inch jointer, Model J-139, is now being produced by the Yates-American Machine Co. The jointer is a heavy duty belt drive machine featuring solid cast iron construction.

An 8 foot by 12 inch table provides support for production. Cutterhead knives can be individually adjusted. The machine is available less motor and switch or with magnetic starter and 5 hp motor. More information in bulletin form is available from the Yates-American Machine Co., Beloit, Wis.

RCI Particle Board Booklet

"Wood Particle Board" is the title of a new RCI booklet recently released. The 16-page booklet contains a discussion of the economics, research and testing in the industry. Available free of charge from Reichhold Chemicals, Inc., RCI Building, White Plains, N. Y.

New Plastic Coating

A clear plastic coating that needs no adhesive backing will be produced by Goodyear Tire & Rubber Co., in a new $9-million plant near Charleston, W. Va., according to BUSINESS WEEK magazine.

The coating, Videne A, can be applied by pressure as a surface for any laminated material, such as plywood, or for paper. Goodyear claims it will remain tight and smooth even while the coated material is being cut and shaped. A polyester film, the coating will be produced in thicknesses from 0.002 to 0.007 inch.

New Drykiln Booklet

Many prefabricated kiln installations in the field are described in a new, 12-page brochure entitled "Standard Prefabricated Dry Kilns". Shown are step-by-step construction illustrations. Available free upon request from Standard Dry Kiln Co., Dept. 365, Indianapolis 21, Indiana.

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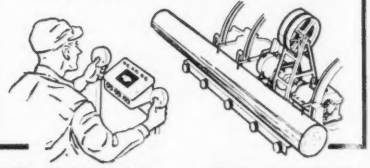
Wilco Machine Works	30-A

WILCO REFUSE BURNER

Three Models. Complete Range of Sizes. Lowest-cost installation. Prefabricated, one-piece panels. Exclusive triple-draft. Sizing engineers available to you.

WILCO MACHINE WORKS, INC.
Municipal Airport • Memphis, Tenn.
P. O. Box 3722 • WHitehall 8–4555

SELECTRIC® sets the pace in sawyer-operated setworks systems.



FROM 2 TO 30 H.P. Write for complete information on the system engineered for your production requirements.

- Greater Sawing Accuracy
- Improved Grade Recovery
- Increased Production
- Lower Operating Costs
- Reduced Maintenance Costs

MILL EQUIPMENT INC.
5219 First Ave. South Seattle 8, Wash.

3 "Best Buys" in continuous moisture control

LAUCKS Sentry

- CUSTOM
- SPECIAL
- MONITOR

CONTINUOUS MOISTURE DETECTORS

Laucks Sentry Monitor, with Brown Electronik Recorder, $4,200. Other systems from $3,550.

Leading firms recently specifying SENTRY equipment include:

DIAMOND MATCH CO.
DWYER LUMBER CO.
HOLLOW TREE LUMBER CO.
INTERSTATE CONTAINER CORP.
PACIFIC PLYWOOD CO.
ST. PAUL & TACOMA LUMBER CO.
SIMPSON LOGGING CO.
SOUTHERN OREGON PLYWOOD CO.
UMPQUAH PLYWOOD CORP.
U. S. PLYWOOD CORP.
WHITE PINE SASH CO.
WOOD CONVERSION CO.

Recognized by the above firms as the "best buy" in today's equipment market, these latest SENTRY systems for measuring, marking and recording the moisture content of a conveyed material accent a new economy, yet maintain the fine standards of precision control that have long been associated with the Laucks name. Write for detailed information.

LAUCKS LABORATORIES, INC.

1201 Poplar Place Seattle 44, Washington
— Leaders in Wood Technology for Fifty Years —

Having developed a

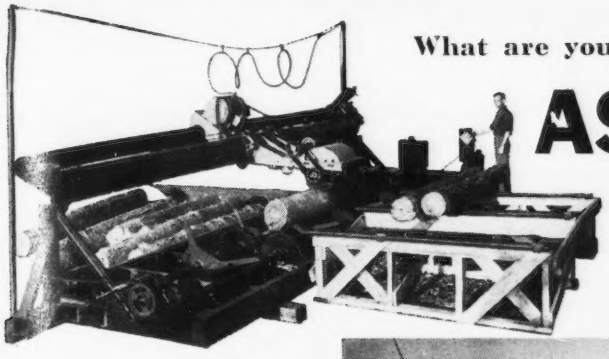
ONE-PRESS CHIPCORE EXTRUSION PLANT

of limited size which could be easily attached to existing furniture factories, we are looking for a suitable experienced agent for the United States able to take over erection and supervision of plants to be installed.

KREIBAUM EXPORT

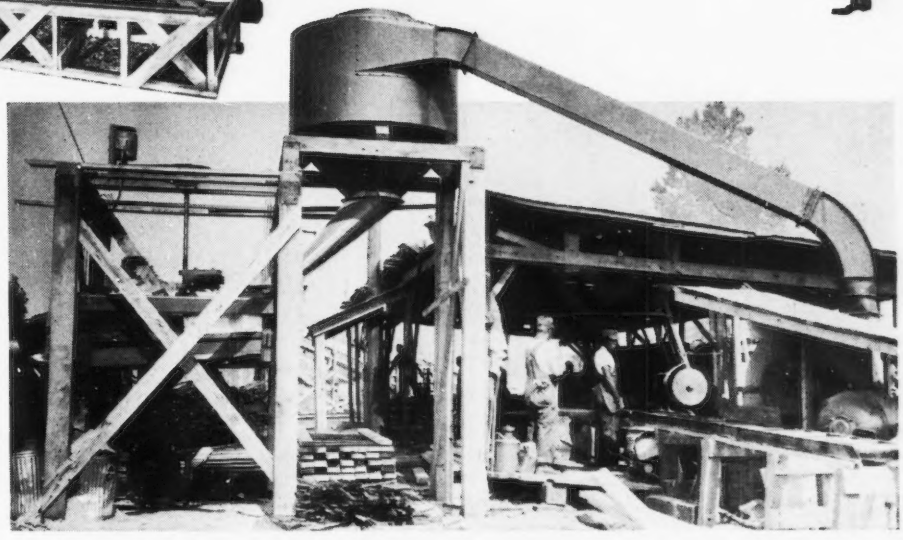
Kommanditgesellschaft

Hannover,–Osterstrasse 2/3, Germany



What are you getting from your scrap . . .

ASH or CASH?



CHIPPING FOR A PROFIT—

Molpus Lumber Company, Philadelphia, Mississippi, cutting from 2 to 2½ MBF of lumber per hour, recently installed a woodwaste utilization setup consisting of Soderhamn DC-6 Log Barker, 48" Horizontal Chipper, and CS-20 Chip Screen. The installation was made at total cost of less than $27,000 excluding high pressure blower system to blow chips 620 ft. to open type gondola car.

Mr. Molpus says of this installation, "We believe this is the lowest cost barker-chipper-screen installation on the market, and it should pay for itself within one and one-half to two years."

IF you're burning waste — slabs, edgings, trimmings — you're missing out on real profits. Here's a minimum-investment installation that will make you

$13,578 to $55,515 profits annually — depending on size of your mill!

A woodwaste utilization installation is no longer just for the "big boys" — this new Soderhamn combination will put you "in the chips!" Efficient, clean barking and chipping . . . accurate, dependable screening — all to most rigid pulp mills' specifications.

TOTAL INVESTMENT LESS THAN $25,000

This is actually the lowest price heavy duty installation on the market. Three precision Soderhamn machines, designed for long life and economical, dependable operation . . . minimum labor, minimum horsepower requirements, minimum maintenance. You can't go wrong with Soderhamn — the line that is setting new standards for the industry.

- *Soderhamn also makes the lowest cost rotor barker on the market, considering installation and labor costs.*

NEW DC-6 LOG BARKER. Will handle efficiently logs from 5" to 36" diam., 6' to 22' long. Production up to 45,000 bd. ft. (Doyle scale) per shift may be reached under ideal conditions, although installation is profitable for mills cutting as low as 7,000 bd. ft. a day.

Interchangeable heads — flail scraper, abrader, and planer types — make it easy to meet all bark specifications. No conveyors needed — skids or live decks may be used for both infeed and outfeed; logs are fed sideways into the barker, and hydraulic kickers discharge barked logs to the rear. Kickers properly spaced to insure support for random length logs.

All movements controlled from one simple station, including start-stop buttons for all motors. Heavier construction than any other low-cost barker on the market. Weight, approximately 12,000 lbs.; cost, complete with all motors, $8,900.

Individual literature available.

48" HORIZONTAL CHIPPER. Adaptable to ground level mill, so no elevated conveyor required. Furnished with 3 high chrome alloy knives and special Soderhamn anvil knife of new, heavier design, affording four usable hard-faced cutting edges. Knives bolt into disc. Chip size readily altered. Average production, 20 cords per hour — more than ample for one barker and screen; weight, approximately 6000 lbs.; HP required, 75-125 depending on conditions; cost, $6,900 plus motor. (Motor can be quoted separately.)

Individual literature available.

CS-20 HORIZONTAL ROTATING CHIP SCREEN. Advanced design Chip Screen insuring quality production of chips — a *must* in today's market conditions. Delivers uniform chips, free of splinters and sawdust. No vertical movement — oversize chips and splinters cannot jump through top screen plate as on conventional chip screen. Chips, sawdust and oversize pieces discharged separately. Requires no ground foundation — suspended from cyclone supporting structure. Average production, 5 cords per hr.; weight, approx. 1600 lbs.; cost complete with 2 HP 1800 RPM motor — $2,200.

Individual literature available.

SODERHAMN MACHINE MANUFACTURING COMPANY

Talladega, Alabama

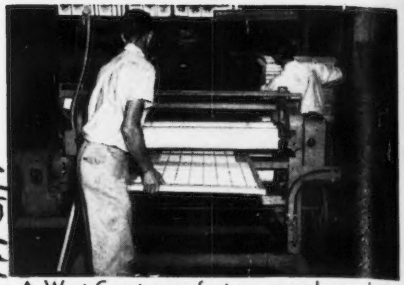
West Coast: Suite 3, 9442 S.W. Barbur Boulevard, Portland, Oregon.

East Canadian Representatives: Forano Limited, Montreal, Canada.

DID YOU GET YOUR COPY?

This brochure describes this 3-machine installation and tells how to figure your profits in advance . . . how to get in the chip business. Write for it now!

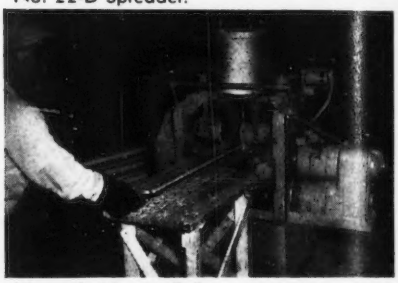
SODERHAMN — FIRST NAME IN WOODWASTE UTILIZATION EQUIPMENT



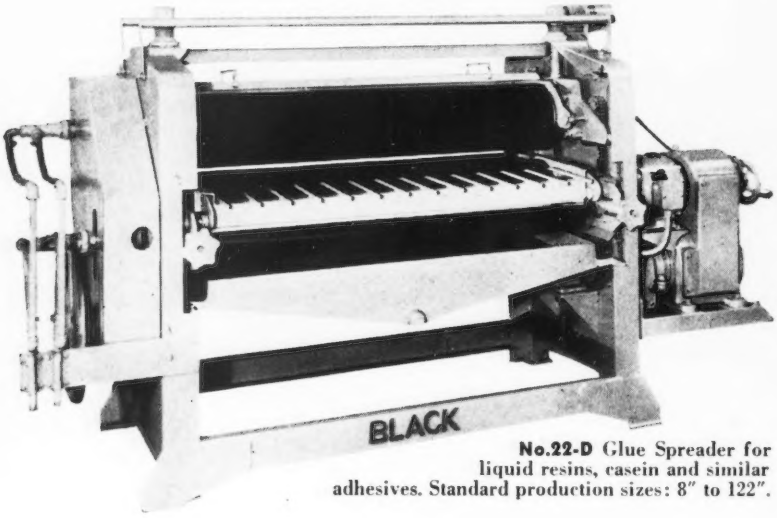
A West Coast manufacturer speeds production of hollow core flush doors with the No. 22-D, 50".

For glue testing and development work, a leading glue manufacturer depends on the No. 22-D Spreader.

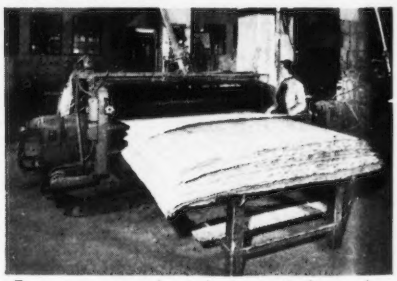
Brilliant New Successes in Gluing and Laminating



Versatile No. 22-D Spreader helps produce laminated beams and roof trusses at a California mill.



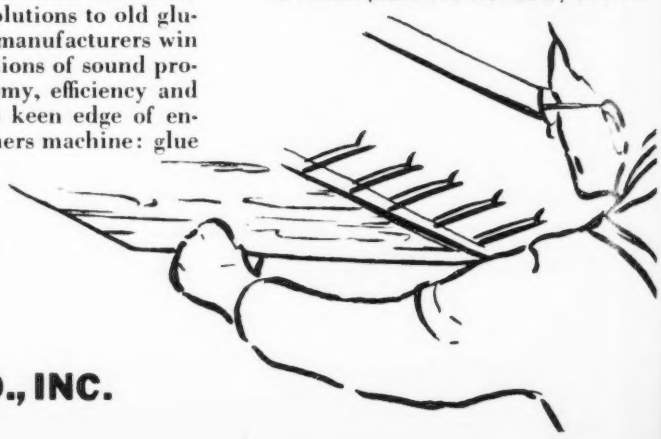
No.22-D Glue Spreader for liquid resins, casein and similar adhesives. Standard production sizes: 8" to 122".



Fast, economical production of plywood in a Finnish plant. The No. 22-D, of course.

On production lines, in glue rooms and laboratories . . . Black Brothers Gluing and Laminating Equipment provides new solutions to old gluing and laminating problems. Helps cost-conscious manufacturers win new competitive markets, too, through new applications of sound production techniques. Preferred for its proven economy, efficiency and speed, the versatile No. 22-D Spreader reflects the keen edge of engineering skill incorporated into every Black Brothers machine: glue spreader, mixer, press or clamp.

Shouldn't you consider a Black Brothers installation? Write for our Supplement to Bulletin No. 11-A which gives construction details and specifications on the No. 22-D Glue Spreader.



THE BLACK BROTHERS CO., INC.

MENDOTA 8, ILLINOIS